

Metacognitive Inquiry via Reflective Tasking Methodology

Julius R. Garzon

Master Teacher III, Libhu National High School, Department of Education, Schools Division of
Maasin City, Philippines

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ABSTRACT

Combining inquiry and metacognition helps strengthen mathematical learning. This study examines how metacognitive mathematical inquiry can be modeled using reflective tasking approach. Quasi-experimental design was employed in two comparable groups of Grade 9 students of Ibarra National High School, Maasin City, Philippines during the academic year 2021-2022. Lesson guides on reflective task assessments anchored on metacognitive and inquiry-based learning theories, inquiry rubric scales and modified state metacognitive inventory served as data collection instruments. Results of t-test analysis revealed significant difference in performance between groups implying high efficacy of the methodology in stimulating students' metacognitive inquiry skill. Correlation values projected significant relationship between reflective learning performances with metacognition. Quantitative evidences, thus, lead to conclusion that reflective tasking methodology exemplifies potential in metacognitive mathematical inquiry as it optimizes their thinking processes, task involvement, and regulation through self-reflection principles worthy of practice throughout lifelong learning.

Keywords: inquiry, reflective task, self-reflection, metacognition, mathematics, experimental

INTRODUCTION

Quality teaching involves not only guiding students in 'how to learn' but also nurturing the development of the skill of 'how to think.' The exploration of mathematics is essential for students to foster critical thinking and problem-solving abilities. Inquiry and metacognition are crucial aspects integral to successful mathematics learning. It is essential to incorporate these learning constructs for students to meet the expectations of the Philippine K12 curriculum. The integration of metacognitive inquiry becomes achievable when students reflect on their actions. This research argues that engaging in reflective tasks serves as an effective model of metacognitive inquiry.

Metacognition, identified as a fundamental characteristic of human cognition (Muhali, 2018), involves the fundamental understanding individuals possess to recognize basic knowledge related to various cognitive tasks. It also encompasses knowledge about employing effective strategies in approaching diverse cognitive tasks through practices such as good planning, providing alternative solutions, and engaging in processes of analysis, synthesis, and evaluation whenever encountering new problems (Tosun & Senocak, 2013). The inquiry learning model has been shown to enhance students' critical thinking, logical reasoning, and creative problem-solving abilities (Suardana et al., 2018; Fuad et al., 2017; Prayogi et al., 2018), ultimately resulting in positive impacts on their learning outcomes (Kizkapan & Bektas, 2017). Emphasizing the crucial role of developing metacognitive skills, Hogan et al. (2015) highlight how it facilitates greater adaptability within social settings. Metacognition contributes to advancing students' cognitive abilities (Hamzah et al., 2022; Nunaki et al., 2019; Nusantari et al., 2021), nurturing creative thinking skills (Jia et al., 2019), and enhancing problem-solving capabilities (Hargrove & Nietfeld, 2015). Moreover, Güner and Erbay's study (2021) discovered that students with high metacognitive skills tend to solve problems correctly by employing appropriate strategies, mathematical notations, and logical reasoning. Garzon and Casinillo

(2021b) revealed that visualizing mathematics through block models significantly maximized text-based problem analysis that stimulates learners' metacognition in strategizing potential solutions effectively. In the evolving landscape of mathematics curricula, it is essential for teachers to provide experiences that foster reasoning and problem-solving skills (Ader, 2019). Metacognitive skills play a crucial role in monitoring and regulating cognitive processes (Chan & Mansoor, 2007), enabling students to understand when, why, where, and how to use their knowledge to successfully solve problems (Carr & Jessup, 1995). The effective implementation of learning strategies is key to empowering the development of metacognitive skills (Amin et al., 2020).

There is a growing interest in how pedagogical agents can offer cognitive, emotional, and metacognitive support to students (Daradoumis & Arguedas, 2020). Several research studies (Chinnery et al., 2019; Hurme et al., 2015) have also investigated various interventions aimed at developing students' metacognitive skills. However, only a few studies have explored the impact of reflective learning tasks on enhancing learners' metacognitive skills in mathematical inquiry. Tusoy and Tan (2022) have confirmed the scarcity of empirical evidence regarding the effects of reflective thinking on metacognitive skills. This gap underscores the importance of integrating reflective learning activities to make mathematics learning engaging, fostering the abstraction of ideas, reflection on strategies, and problem-solving discourse, especially in the context of new normal education. Integrating metacognitive learning is crucial for alleviating learners' difficulties in grasping and understanding concepts. Fritz et al. (2019) and Ferrettiet al. (2022) assert that difficulties in learning mathematics manifest as students' challenges in understanding mathematical processes and struggling with tasks involving numbers or mathematical symbols. The effectiveness of the metacognitive strategy is evident; however, it needs to be revisited to ascertain its effect on students' mathematics achievement (Sercenia&Prudente, 2023).

The reflective tasking approach outlined in this study entails participating in critical tasks guided by focused questions. These questions direct learners to incorporate thought processes and cognitive strategies for exploring concepts, emphasizing inquiry. This approach encourages students to delve into concepts while being mindful of the steps they took and their approach to the task, promoting metacognition. The integration of both inquiry and metacognition is essential for students to enhance their comprehension of mathematical concepts and their practical application in real-life scenarios. Reflective tasking emerges as a pivotal intervention for students' metacognitive development, addressing the challenges of 21st-century classroom learning. In this context, the realm of mathematical inquiry becomes significantly relevant to fostering competence and achieving success in life.

RESEARCH QUESTIONS

Generally, this study aims to investigate the efficacy of reflective tasking approach as a potential metacognitive mathematical inquiry model in mathematics learning. Specifically, this research sought to answer the following questions:

1. What is the level of metacognitive skills in mathematical inquiry of students exposed and not exposed to reflective-tasking methodology in terms of pretest and posttest scores?
2. Is there a significant improvement of metacognitive skills in mathematical inquiry of students exposed to reflective tasking methodology?
3. Is there a significant difference of metacognitive skills inquiry between students exposed and not exposed to the reflective intervention?
4. Is there a significant relationship between achievement and metacognitive inquiry skills in mathematics?

Theoretical and Conceptual Framework

This study is based on Flavell's Metacognitive Theory and Bruner's Constructivism. Metacognition

involves the capability to consciously control processes such as planning, monitoring progress, allocating effort, using strategies, and regulating cognition. According to Flavell (1978), metacognitive theory comprises two areas of study: knowledge and processes. Metacognitive knowledge includes the understanding of how minds work in general and how one's own mind operates. Metacognitive processes involve planning, monitoring, and regulating thoughts, generally known as executive processes.

Bruner's (1990) theory proposes that constructivist learning is a process where learners build upon present and past information. In constructivism, the primary principle is that individual learners must actively construct knowledge and skills. Students can take information, generate ideas, and make choices by utilizing a thoughtful process. Inquiry refers to the set of behaviors involved in a person's quest for reasonable explanations about phenomena that intrigue them. This study conceptually adopts a reflective tasking approach as the independent variable, while metacognitive skills in inquiry-based learning serve as the dependent variable."

These changes help improve the flow and clarity of the content by restructuring some sentences and ensuring consistency in the description of the theories and concepts mentioned.

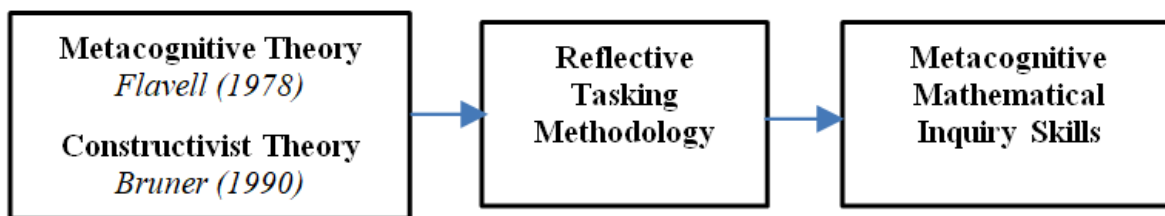


Figure 1. Theoretical and Conceptual Framework

METHODOLOGY

This study is a quantitative research utilizing quasi-experimental design. There were two intact comparable groups, control and experimental, comprising 30 respondents each of Ibarra National High School, Maasin City Philippines during the Academic Year 2021-2022. Control group was exposed to conventional method (usual lecture discussion without reflective tasking) while the experimental group was taught same content but with the integration of reflective tasking activities anchored on metacognitive and inquiry-based principles. For data collection, this study adopted the State Metacognitive Inventory (SMI) by O'Niel and Abedi (1996) as cited in Alizadeh,(2019) to assess student's level metacognitive skills in inquiry-based tasks. Validated formative assessments and inquiry-based Lesson guides integrating reflective tasking methodology were also designed to guide instruction and assessment for experimental group.

RESULTS AND DISCUSSION

Assessment Result of Students' metacognition in mathematical inquiry between control and experimental groups

Table 1 below is a cross-analysis of scores showing a level of increase in scores in experimental (1.5pts) than control group (0.47 pts). This implies that integrating reflective tasks into mathematical inquiries can promote metacognition among students. Those who engage in thorough reflections on their work tend to enhance their metacognitive abilities, making them more active in their thinking compared to those who do not engage in reflection. This assertion is supported by Chen et al. (2019), who claimed that when students become aware of and can actively govern their own learning through reflective thinking, they can assess what they know, identify what they need to know, and bridge that gap in learning contexts, thereby

facilitating learning. Furthermore, Yilmaz and Keser (2016) support the idea that in environments where reflective thinking activities are present, students take on more individual responsibility and become more conscious of their cognitive processes.

Table 1. Level of Metacognitive Inquiry skills through Reflective Tasking

	Control Group		Experimental Group	
	Pretest	Posttest	Pretest	Posttest
Mean	1.85 (Low)	2.32 (Low)	2.20 (Low)	3.82 (Very High)
Standard Deviation	4.7	5.22	3.60	4.02
Description	<i>Very Low</i>	<i>Low</i>	<i>Low</i>	<i>Very High</i>

Legend: Very Low (1.00 – 1.74) Low (1.75 – 2.49) High (2.50 – 3.24) Very High (3.25– 4.00)

Test Results on the Significance of improvement of Students’ Metacognitive Skills in Mathematical Inquiry through engagement in Reflective Tasking methodology

The analysis conducted using a Paired t-test in Table 2 revealed a significant improvement in students’ metacognitive skills in the inquiry process from pretest to posttest data ($t=12.33$, $df=29$, $p=0.000$). This implies that metacognitive skills of learners are evident as they perform reflective tasks in mathematics. These learners are becoming more inquisitive in finding reasons and explanation to the solutions that they have performed in performance tasks. As a result of their reflective performance, the students are likely to arrive at the correct and logical response.

The finding aligns with the research conducted by Tusoy and Tan (2022) which showed that reflective strategies aided learners to reflect, evaluate, improve and recall what they have learned on the previous lessons. It also helped them to increase their performance because they were able to know what or where they need to improve more (Ningsih & Rohana, 2016). Furthermore, Garzon and Casinillo (2021a) supported the notion that guided inquiry tasks are conducive to producing positive learning outcomes in students who possess metacognitive and reflective capabilities. Likewise, Amal and Mahmudi (2020) supports that utilizing metacognitive strategies to enhance self-efficacy can lead to significant academic effectiveness for students, particularly in cognitive areas like reasoning, communication skills, and problem-solving abilities.

Table 2. Significance of Improvement in skills of Students Exposed to Reflective Tasking interventions

Tests Compared	Paired Differences			df	Sig. (2-tailed)
	Mean	Std. Deviation	t		
Pretest Experimental Group to Posttest Experimental Group	3.06	2.24	12.33*	29	0.000

* test result is significant at $p\text{-value} < 0.01$

Test Results on the Significance of Difference of Metacognitive Skill in Math Inquiry between Students Exposed and Not Exposed to Reflective Tasking Methodology

Table 3 reflects the independent sampled t-test values with the assumption of equal variances via Levene’s test of homogeneity. Highly significant difference ($t=3.88$, $df=29$, $\alpha=0.000$) was observed in the skills between students exposed and not exposed to the reflective tasking approach. This implies that students’ engagement in reflective tasks experiences developed higher metacognition and inquiry capacity than those who are not ($M\text{-difference}=1.50$). This provides evidence that students who receive effective instruction in

metacognitive skills demonstrate greater advancement compared to those who do not. Likewise, students who possess robust metacognitive abilities are in a favorable position for enhanced learning and superior performance compared to their peers who are still in the process of developing their metacognition. Thus, through reflective tasking, metacognitively aware students are able to acknowledge their cognitive capacities, guide their own learning process, assess their performance, comprehend the factors contributing to their successes or failures, and acquire new strategies. This enables the learners to be more participative and engaged in the exploration of new concepts and techniques that guide them succeed the problem-solving tasks efficiently.

Tusoy and Tan (2022) revealed that metacognitive skills was at high level because of reflective thinking approach. This indicates that through reflective tasks, learners are able to think how they learn which strengthen their metacognitive potential. Moreover, Erdogan(2019) reiterates that a cooperative learning that is supported by reflective thinking activities could have a positive effect on students’ critical thinking skills and metacognitive skills. Amal and Mahmudi (2020) suggest that the utilization of metacognitive strategies requires teachers to effectively engage and influence all facets of students in the process of learning mathematics, particularly focusing on the cognitive and self-efficacy domains.

Table 3. Significance of Difference of Posttest Skills in Inquiry-based Mathematics between Control and Experimental Groups

Test Compared				t-test for comparison of means			
		Test Used	Control	Experimental	Mean Difference	t	df
Post test	Independent Two-Sample t-test	2.32	3.82	1.50	3.88	29	0.000

Note: Levene’s Test: F-value= 0.315, sig. value=0.839; equal variances assumed. Result is highly significant at $p < 0.01$)

Test Results on the Significance of Relationship between Students’ Metacognitive Inquiry and their Mathematics achievement

Pearson r values shown in table 4 at 5% significance level indicated a significant relationship between students’ metacognitive skills and their performance in inquiry-based Mathematics in the experimental group (p -value=0.003) but not in control group (p -value=0.104). Hwang and Vrongistinos (2009) supports that students who are “metacognitively aware learners” demonstrate better academic performance. Albayrak,

et al. (2018) emphasized that students’ effective participation in the problem-solving process from the beginning to the end by thinking on the problems and bringing recommendations for solution may be considered to be a result of reflective thinking.

The findings of Sercenia and Prudente (2023) showed that metacognitive-based pedagogical intervention has a significantly large and positive effect on students’ mathematics achievement. Deringol (2019), on the other hand, also revealed that reflective thinking has a significant relationship with mathematics academic achievement. It is useful to integrate reflective activities to develop mathematical comprehension and other mathematics-related activities. Reflection can make it possible for students to be metacognitively responsive to their cognitive process, encourage deep understanding, monitor what they have learned, appreciate the learning experiences, and evaluate the learning process and performance (Kim, 2005). Several studies (Csíkos & Steklács, 2010; Roll et al., 2011; Naseri et al., 2017; Naful et al., 2021) that were cited by Wafubwa, and Csikos (2022) supports the finding that training students’ metacognition influenced learning outcomes positively. They concluded that self-assessment emphasizes high levels of metacognition, which influence learning styles and consequently learning achievement.

Table 4. Relationship between Achievement and Metacognitive inquiry skills

Groups	Variables Tested	Test Used	r	p-value	Interpretation
Control Group	Performance and Metacognition	Pearson r	0.208*	0.104	Not Sig.
Experimental Group			0.712*	0.003	Sig.

relationship is significant at $p < 0.05$

CONCLUSION AND RECOMMENDATIONS

Generally, reflective tasking approach effectively and efficiently helps students' become more metacognitive and self-regulated in mathematical inquiry learning as it draws them towards conscious control processes of planning, progress monitoring, effort allocation, strategy use and regulation of cognition. Letting students think about how they think across inquiry-based challenges attest the positive impact of reflective tasking methodologies in improving academic achievement worthy of practice throughout lifelong learning. This study recommends teachers to integrate reflective tasking approaches on their mathematics teaching to help capacitate students with metacognition to sustain thinking skills in inquiry-based task performance. Furthermore, teachers should integrate reflective tasking by consistently engaging learners in different open-ended questions about the mathematical tasks which can be implemented through different methodologies such as reflection logs, metacognitive talk, traffic lights, KWL, blogging or eJournal and reciprocal teaching.

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