Enhancing Metacognitive Awareness, Skills, and Academic Performance: A Study on the Impact of Performance-Based Assessment with Metacognitive Prompts in Quadratic Functions Using the RME Approach

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Abstract: Assessments play a pivotal role in Mathematics education, serving as vital gauges of students' mathematical proficiency and informing teaching strategies. Despite calls for contextualization, some educators still rely on abstract teaching methods and decontextualized tasks. This study aims to address these concerns by designing and implementing a performance task on quadratic functions, following a realistic mathematics education approach, coupled with metacognitive prompts. Using mixed methods, pre-test and post-test scores from the Jr. MAI of 30 Grade 9 students, their responses to metacognitive prompts, performance task scores, and interview questionnaire responses were analyzed. Statistical analysis revealed significant improvements in students' metacognitive awareness and skills, particularly in knowledge about cognition and regulation of cognition. Strong positive correlations were observed between variables. Descriptive analysis indicated an increase in students scoring above the cut-off post-intervention. Thematic analysis of student interviews highlighted themes such as pre-task planning, progress monitoring, and post-task evaluation, underscoring enhancements in self-knowledge and mathematical performance.

Keywords: Realistic Mathematics Education, Authentic Assessments, Metacognitive Prompts, Metacognition in Mathematics

INTRODUCTION

In contemporary mathematics education, there is a growing emphasis on evaluating students' ability to apply learned concepts to real-world situations, moving beyond traditional assessments that focus solely on procedural fluency. Educators continually strive to develop effective teaching strategies and tools aimed at enhancing student comprehension and performance in mathematics. As such, performance-based assessments have emerged as effective tools in this regard, enabling educators to gauge students' conceptual understanding, problem-solving skills, and strategic thinking (Bender, 2020).

Within the Philippine educational context, the Department of Education mandates the inclusion of performance tasks as integral components of both formative and summative assessments. These tasks are designed to assess students' mastery of competencies by requiring them to engage in meaningful, context-rich activities that mirror real-life challenges (Department of Education. 2020).These tasks are intended not only to test knowledge but to provide opportunities for students to apply mathematical concepts in context-rich, meaningful activities that reflect real-life challenges. In practice, performance tasks are often implemented at the end of instructional units to assess mastery of competencies (summative), but they can also be used throughout instruction to provide ongoing feedback and inform teaching (formative). However, the implementation of performance tasks often faces challenges, such as a lack of emphasis on students' metacognitive processes during task completion (Pranena & Pascima, 2023).

Recent studies underscore the significance of integrating metacognitive elements into performance assessments. For instance, Kadir (2022) highlights that performance assessments incorporating problem-solving and problem-posing strategies, aligned with students' metacognitive levels, can enhance mathematical achievement. Similarly, Mertasari et al. (2023) emphasized that formative performance assessments positively impact students' metacognitive abilities, fostering skills like planning, monitoring, and evaluating their learning processes.

Despite these findings, there remains a gap in effectively capturing students' metacognitive engagement during performance tasks. Addressing this, the study aims to answer the following research questions:

1. Can performance-based assessments with the metacognitive prompts in quadratic functions using the RME approach contribute to students' metacognitive awareness, skills and overall mathematical performance?
2. How do students perceive the completion of a performance-based assessment with metacognitive prompts in mathematics, and what is their perceived impact on learning outcomes?

Through this, deeper insights into how structured reflection and guided questioning, grounded in the principles of Realistic Mathematics Education (RME) can promote deeper insights into students' mathematical thinking, strengthen conceptual understanding, and improve academic performance.

LITERATURE REVIEW

Realistic Mathematics Education

Mathematics, contrary to common perceptions, emphasizes problem-solving, critical thinking, and innovation over rote memorization (Boaler, 2016). Realistic Mathematics Education (RME) has emerged as a successful approach to fostering motivation, self-confidence, problem-solving abilities, and reasoning skills among students (Laurens et al., 2017). By engaging students in contextual problem-solving exercises relevant to their experiences, RME aims to enhance cognitive achievement in mathematics (Bonotto, 2008).

RME is guided by six core teaching principles: activity, reality, level, intertwinement, interactivity, and guidance (Heuvel-Panhuizen and Drijvers, 2014). These principles underscore the importance of student engagement, real-life application, progressive learning, integration of mathematical concepts, social interaction, and teacher guidance.

Performance-based assessments aligned with RME should be authentic, incorporating tasks meaningful to students' abilities and values (Bland & Gareis, 2018). Such assessments provide opportunities for students to develop metacognitive skills, enabling them to effectively solve problems and apply learned concepts to real-world scenarios (Rhodes, 2019). Additionally, prompting plays a crucial role in guiding learners on when and why to employ specific problem-solving approaches (Alzahrani, 2017). In fact, Fauziah et al. (2018) conducted a study on the implementation of authentic assessment in math education, finding that it enhances students' math learning outcomes and fosters active participation from both teachers and students, both in and out of the classroom. Similarly, Winarso (2018) corroborated these findings, demonstrating that students who underwent authentic assessments showed better math learning outcomes compared to those who did not. In line with these, Sari et al. (2022) developed and validated worksheets grounded in RME, showing that students using RME-based worksheets demonstrated improved mathematical communication and engagement through contextual problem-solving activities.

Self-Assessments in Mathematics

To promote comprehensive understanding and critical thinking skills in mathematics, educators must employ varied assessment methods, including performance-based assessments (Alzahrani, 2017). These assessments challenge students to apply their knowledge and skills in practical contexts, fostering authentic learning experiences (Department of Education, 2015; Bland & Gareis, 2018 cited in Wiggins, 1993). However, challenges remain in providing timely and relevant feedback to students, necessitating innovative assessment strategies and remote monitoring systems (Delgado, 2020; Department of Education, 2020).

Many educational institutions persist in presenting mathematics as abstract and detached from real-world contexts, despite recommendations advocating for contextualization (Minaar, 2015 cited in Sandi-Urena et al., 2010). This approach limits authentic learning opportunities and deprives students of deeper learning experiences, such as reflection, crucial for their development (Andrade, 2019; Estrada, 2021). In response to these challenges, the National Council of Mathematics Supervisors (NCSM) and the National Council of Teachers of Mathematics (NCTM) recommend adapting instructional techniques and assessment practices to support student learning (Delgado, 2020). This includes fostering meaningful mathematical conversations and encouraging students to document their ideas using various tools and representations (NCTM, 2020). Moreover, students are encouraged to engage in self-assessment to monitor their progress and tailor learning strategies to their strengths, while teachers are tasked with providing meaningful feedback to facilitate improvement (Al-Bashir et al., 2016). After all, educators must continue to explore innovative teaching methods and adapt educational practices to meet the evolving needs of students in current learning environments (Lao & Divinagracia, 2021).

Metacognition in Mathematics

Metacognition, as defined by various scholars, encompasses the processes through which students regulate their cognition, encompassing both their thoughts and behaviors (Rhodes, 2019; Chick, 2013). It comprises three main components: metacognitive knowledge, metacognitive experiences, and metacognitive skills (Laycraft, 2019). Metacognitive knowledge involves an understanding of mathematical processes and the nature of mathematics itself (Tian et al., 2018 cited in Özsoy, 2011). Metacognitive experiences, on the other hand, involve the feelings and judgments students have about learning activities, impacting both cognitive and affective processes (Efklides, 2009). Finally, metacognitive skills encompass purposeful techniques used to regulate cognition, such as planning, monitoring, and evaluating one's learning progress (Laycraft, 2019 cited in Veenman & Elshout, 1999).

These metacognitive processes have the potential to enhance students' learning experiences and academic performance in mathematics (EduCare, 2020). By enabling students to think critically and make connections between concepts, metacognition fosters a deeper understanding of mathematical concepts (Alzahrani, 2017 cited in Grant, 2014). However, traditional feedback mechanisms may fall short in supporting students' metacognitive development, necessitating innovative approaches to assessment and task design (Fogarty, 1994). With this, teachers play a crucial role in promoting metacognitive development by guiding students through the three-phase process of metacognition: planning, monitoring, and evaluating (Fogarty, 1994). By integrating metacognitive questioning techniques into lesson plans, teachers can help students develop self-awareness and problem-solving skills (Ahdhianto et al., 2020). Additionally, fostering metacognitive activities such as self-explanation and self-assessment can enhance students' academic success and overall learning experience (Setiawan & Supiandi, 2018; Lin, 2001). In fact, Ozdemir et al. (2024) found that mathematical metacognition awareness significantly contributes academic resilience.

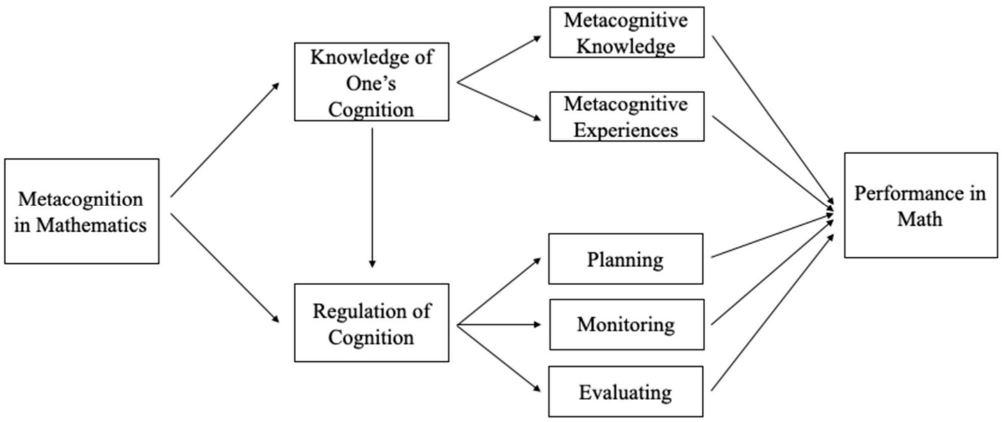

Figure 1: Theoretical Framework Adapted from Garofalo (1986)

Figure 1 shows that metacognitive knowledge and processes play a crucial role in shaping students' mathematical performance, influencing how they approach and execute cognitive tasks. Integrating a metacognitive dimension into classroom practices benefits both teachers and students by enhancing students' cognitive processing and ultimately improving their mathematical performance. This distinction in metacognition encompasses understanding one's cognitive processes and regulating them, impacting how students prepare and execute cognitive tasks, thereby affecting their mathematical performance.

Various studies emphasize the efficacy of metacognitive activities in enhancing students' metacognitive skills and performance in math. Wen-Xin et al. (2015) observed a significant improvement in students' inquiry practices, particularly in planning and analysis skills, through the use of metacognitive prompts. Additionally, Ysseldyke and Tardrew (2008) highlighted the benefits of incorporating instructional management and progress monitoring tools in ongoing math instruction, leading to improved math outcomes for students.

Overall, fostering metacognitive skills empowers students to become more self-aware learners, capable of monitoring their progress, identifying areas for improvement, and applying effective learning strategies (Chick, 2013 cited in Bransford, Brown, & Cocking). By integrating metacognitive activities into mathematics education, educators can enhance students' problem-solving abilities and promote a deeper understanding of mathematical concepts.

METHODS

Research Design

The study used an action research design, incorporating both qualitative and quantitative data to evaluate the impact of metacognitive prompts within performance-based assessments using the RME approach on students' metacognitive awareness, skills, and academic performance. The study utilized purposive sampling to select 30 Grade 9 students. The criteria for selecting the students include: (1) active enrollment in Grade 9 during the conduct of the research; (2) consistent participation in performance-based tasks throughout the quarter; and (3) evidence of diverse learning styles and abilities based on classroom observations and formative assessments. Based on the researcher's assessment of the students, nine (9) participants were selected, representing varying proficiency levels: three below average, three average, and three above average students. The classification was based on a triangulation of their academic performance in Mathematics from the previous quarters, classroom engagement, and the quality of outputs in their performance-based tasks. Below-average students consistently scored at least one standard deviation below the class mean, average students performed within the mean range, and above-average students consistently scored above the mean. This selection ensured a representative sample to meaningfully explore metacognitive behaviors across proficiency levels.

Research Instruments

The research instruments used in the study were developed by the researcher. The first one is the performance-based assessment incorporating metacognitive prompts into students' supplementary materials, focusing on quadratic functions. The performance-based assessment task involves crafting a business proposal that integrates profit maximization principles using quadratic functions, tailored to students' personal preferences. On the other hand, the metacognitive prompts were divided into three sections: "before", "during", and "after", comprising insightful questions regarding their task experiences. Aligned with Philippines' Department of Education guidelines, these prompts served as self-monitoring tools. Additionally, specific analytic rubrics were crafted for each task, prioritizing process quality over product outcomes. Four teachers, including the Math Department coordinator, a UNIPEAT author, a head teacher and MTAP trainer, and a Math education professor, validated the performance-based assessment and rubric. To evaluate student metacognition, the Junior Metacognitive Awareness Inventory (Jr. MAI) adapted from Sperling, Howard, Miller, and Murphy in 2002 was administered, along with a parallel tool scoring students' metacognitive skills from their prompt responses. Semi-structured interview questionnaires were also designed by the researcher, validated by the same validators, to gather student experiences and perceptions on task completion with metacognitive prompts, as well as the researcher's assessment of students' metacognitive skills and Mathematics performance. Zoom was used for interviews, with recorded sessions for reference.

Data Gathering Procedure

Participants were provided with informed consent forms before the implementation of the study. Upon consent, students completed the Jr. MAI to establish baseline data, to be compared with post-intervention responses. The researcher then conducted a lesson on Quadratic Functions, followed by the distribution of the performance-based assessment incorporated with metacognitive prompts. The task was assessed using the analytic rubric to monitor progress and offer feedback. Subsequently, students were asked to accomplish the Jr. MAI for the second time. On the other hand, the researcher evaluated students' metacognitive skills based on their prompt responses using a parallel Jr. MAI questionnaire. Comparisons were made between student scores and the researcher's scores. Additionally, participants were interviewed via Zoom at agreed-upon times, with note-taking and recording for data preservation and analysis.

Data Analysis

The study used both quantitative and qualitative analyses to examine the gathered data. Quantitatively, several statistical methods were applied to assess learners' metacognitive awareness and skills in Mathematics. This included calculating means from pre-test and post-test scores on the Jr. MAI. A Paired Samples t-test was utilized to determine significant differences between Grade 9 students' pre-test and post-test results. Cohen's d was also employed to gauge the effect size of these differences. Additionally, the Shapiro-Wilk Test and Wilcoxon Matched-Pairs Signed-Ranks Test were conducted to assess normality in student scores. Pearson Correlation Coefficient was used to measure the association between students' Jr. MAI scores and the researcher's average scores on metacognitive skills, as assessed through the parallel Jr. MAI questionnaire. Descriptive analysis was also used to compare the number of students scoring above, equal to, or below the cut-off between previous and current performance tasks.

On the other hand, thematic analysis was used to analyze the qualitative data gathered from the interviews with the participants. This approach involved examining their responses to identify commonalities and connections within the data, ultimately leading to the creation of overarching themes. The process included coding the data to systematically organize and interpret the information, thereby highlighting key insights, patterns, and outcomes.

RESULTS

Jr. MAI Mean Scores Before and After the Intervention

The analysis of students' mean scores on the Jr. MAI revealed insightful patterns within the categories of Knowledge about Cognition and Regulation of Cognition.	**Pre-Test Mean**	**Post-Test Mean**
Knowledge about Cognition		

• Declarative Knowledge	3.41	3.98
• Procedural Knowledge	3.37	4.07
• Conditional Knowledge	3.52	4.17
Mean	**3.43**	**4.07**
Regulation of Cognition		
• Planning	3.38	4.07
• Monitoring	3.32	3.86
• Evaluating	3.33	3.99
Mean	**3.34**	**3.97**
Overall Mean	**3.39**	**4.02**

Table 1. Jr. MAI Pre-test and Post-test Scores Before and After the Intervention

Table 1 shows the pre-test and post-test mean scores for each sub-component within these categories. Following the intervention, notable improvements were observed across all sub-components. Among the sub-components related to *Knowledge about Cognition*, *Conditional Knowledge* demonstrated the highest mean score post-intervention (4.17), indicating a substantial increase from the pre-test. Similarly, *Procedural Knowledge* and *Declarative Knowledge* exhibited notable improvements, with mean scores of 4.07 and 3.98, respectively.

In terms of *Regulation of Cognition*, the sub-component *Planning* displayed the highest mean score post-intervention (4.07), reflecting a notable increase from the pre-test. *Evaluating* and *Monitoring* also showed considerable improvements, with mean scores of 3.99 and 3.86, respectively.

Futhermore, the overall mean scores for *Knowledge about Cognition* and *Regulation of Cognition* indicate that the pre-test mean score for *Knowledge about Cognition* was 3.43, increasing to 4.07 post-intervention, while *Regulation of Cognition* increased from 3.34 to 3.97. Overall, there was a notable improvement in metacognitive awareness and skills, with the combined mean score rising from 3.39 pre-test to 4.02 post-intervention.

Normality Test for Jr. MAI Pre-Test and Post-Test Scores of the Students

In addition to the paired sample t-test, we conducted the Shapiro-Wilk test to assess the normality of the pre-test and post-test scores for each sub-component of the Jr. MAI. For *Declarative Knowledge*, the pre-test scores showed a p-value of 0.157 and the post-test scores showed 0.029, indicating normality only in the pre-test scores. Conversely, both pre-test and post-test scores for *Procedural Knowledge* departed significantly from normality with p-values of 0.001 and 0.035, respectively. However, the pre-test and post-test scores for *Conditional Knowledge* showed no evidence of non-normality with p-values of 0.053 and 0.095, respectively.

Moving to the sub-components of *Regulation of Cognition*, both pre-test and post-test scores for *Planning and Evaluating* exhibited p-values greater than 0.05, suggesting normality. However, *Monitoring* displayed normality only in the pre-test scores ($p = 0.061$), while the post-test scores deviated from normality ($p = 0.012$).

Given the departure from normality in several sub-components, the non-parametric Wilcoxon Matched-Pairs Signed-Ranks Test for further analysis. The results show that all p-values are less than 0.05, indicating statistically significant differences between pre-test and post-test scores for these sub-categories.

Impact of the Intervention on Students' Metacognitive Awareness and Skills

The effect of implementing a performance task with metacognitive prompts in Mathematics on the metacognitive awareness and skills of Grade 9 students was rigorously assessed, focusing on their Knowledge about Cognition and Regulation of Cognition

Paired Samples Test and Effect Size		
	p-value	**Cohen's d**
PRETEST - POSTTEST	0.001	1.094

Table 2. Paired Sample t-Test of the Grade 9 Students' Overall Jr. MAI Scores and Treatment Effect of the Intervention

The paired sample t-test results in Table 2 reveal a significant difference ($p < 0.05$) between the Jr. MAI pre-test and post-test scores of the students, indicating an improvement in metacognitive awareness and skills following the intervention. This improvement was particularly notable after incorporating metacognitive prompts related to quadratic functions.

To delve deeper into the Jr. MAI scores, Cohen's d value was calculated to gauge the magnitude of the difference between the pre-test and post-test scores of Grade 9 students. It shows a Cohen's d value of 1.094, indicating a very strong treatment effect. This underscores the substantial positive impact of utilizing a performance task with metacognitive prompts on the overall metacognitive awareness and skills of the students. The intervention emerged as an effective tool for enhancing students' ability to manage their thinking processes.

To further dissect the findings, an in-depth analysis was conducted on the significant differences and treatment effects of each sub-component within the two categories. Specifically, the following paired comparisons were analyzed: KACPRE–KACPOST (Knowledge About Cognition Pre-test and Post-test), DECPRE–DECPOST (Declarative Knowledge Pre-test and Post-test), PROPRE–PROPOST (Procedural Knowledge Pre-test and Post-test), and CONPRE–CONPOST (Conditional Knowledge Pre-test and Post-test).

Paired Samples Test and Effect Size		
	p-value	**Cohen's d**
KACPRE-KACPOST	0.001	1.134
DECPRE-DECPOST	0.001	0.809
PROPRE-PROPOST	0.001	0.920
CONPRE-CONPOST	0.001	0.928

Table 3. Paired Sample t-Test of Grade 9 Students' Pre-test and Post-test Scores in Knowledge about Cognition and its Sub-components and Effect Sizes of the Intervention

As shown in Table 3, significant differences ($p < 0.05$) were observed in both the Knowledge about Cognition category and its sub-components, highlighting increased metacognitive awareness post-intervention. Moreover, Cohen's d values were calculated to reveal the effect sizes of these differences.

On the other hand, it also shows the substantial effect size (Cohen's d = 1.134) of the category Knowledge about Cognition, particularly in Conditional Knowledge, Procedural Knowledge, and Declarative Knowledge. These findings underscore the intervention's efficacy in enhancing students' understanding and application of metacognitive strategies.

In addition, the following paired comparisons were analyzed to examine the changes within the Regulation of Cognition category: ROCPRE–ROCPOST (Regulation of Cognition Pre-test and Post-test), PLANPRE–PLANPOST (Planning Pre-test and Post-test), MONPRE–MONPOST (Monitoring Pre-test and Post-test), and EVALPRE–EVALPOST (Evaluating Pre-test and Post-test).

Paired Samples Test and Effect Size		
	p-value	**Cohen's d**
ROCPRE-ROCPOST	0.001	0.811
PLANPRE-PLANPOST	0.001	0.847
MONPRE-MONPOST	0.005	0.559
EVALPRE-EVALPOST	0.003	0.595

Table 4. Paired Sample t-Test of Grade 9 Students' Pre-test and Post-test Scores in Regulation of Cognition and its Sub-components

Table 4 shows the significant differences ($p < 0.05$) in both the Regulation of Cognition (ROC) category and its sub-components, indicating improved metacognitive skills post-intervention. Cohen's d values were also calculated to assess the effect sizes of these differences. It also highlights a significant treatment effect (Cohen's d = 0.811) in the category Regulation of Cognition, particularly in Planning, Monitoring, and Evaluating. These results underscore the intervention's role in fostering students' ability to approach learning tasks strategically and evaluate their progress effectively.

The data suggest that the intervention significantly enhanced students' metacognitive skills, facilitating their ability to plan, monitor, and evaluate their learning processes. Despite varying effect sizes, the overall improvement underscores the importance of consistently engaging in metacognitive activities to achieve academic goals effectively.

Relationship between Participants' Scores and Researcher's Scores

To explore the correlation between students' average Jr. MAI scores and the researcher's scores, the Pearson correlation coefficient was utilized.

The result reveals a strong positive correlation (Pearson $r = .703$) between students' average Jr. MAI scores and the researcher's scores. This correlation is highly significant ($p < .001$), indicating that the researcher's assessment aligns closely with the students' self-reported metacognitive prompts.

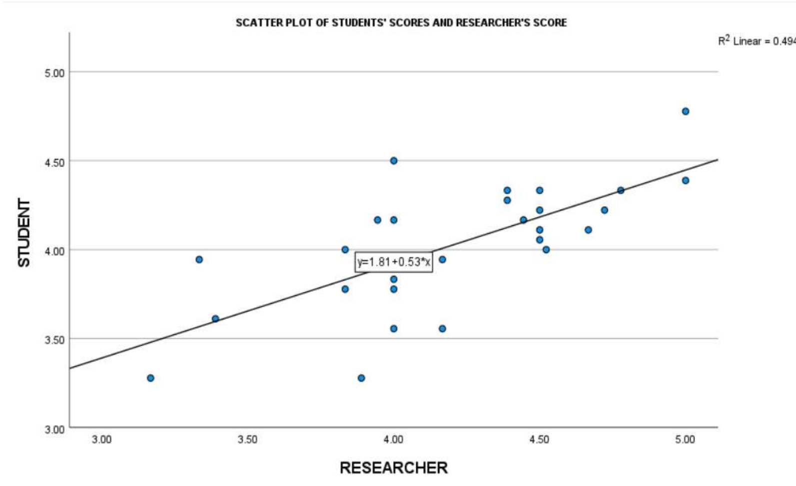

Figure 2. Scatter Plot with Regression Line of the Students' Scores and Researcher's Scores

A scatter plot, depicted in Figure 2, further illustrates this strong positive relationship, suggesting a moderate linear correlation.

To assess the intervention's impact on overall performance, descriptive analysis was conducted to determine the number of students scoring above and below the established cut-off on their performance-based assessment before and after the intervention.

	Number of Students Scored Above or Equal to the Cut-off	**Number of Students Scored Below the Cut-off**
Pre-Intervention	26	4
Post-Intervention	28	2

Table 5. Frequency Table of the Number of Students who Scored Above, Equal and Below the Cut-off

Table 5 shows the number of students who scored above, equal to, and below the established cut-off (75% passing score) on their performance-based assessment before and after the intervention. Before the intervention, 26 students achieved scores at or above the cut-off, while 4 students scored below it. Following the intervention, 28 students met or exceeded the cut-off, with only 2 students falling below it.

Students' Perspectives on Completing a Performance-Based Assessment with Metacognitive Prompts in Mathematics

A thematic analysis was conducted to extract significant quotes from students, providing a comprehensive insight into their experiences and viewpoints regarding the metacognitive intervention. The analysis focused on two predetermined categories: students' perceptions of completing a performance-based assessment with metacognitive prompts and the perceived impact of this intervention on their learning.

Themes	Codes		
	Below Average Group	**Average Group**	**Above Average Group**
Planning before the accomplishment of the performance task about quadratic functions	Usage of prior knowledge on quadratic equations and prior experiences Communication of mathematical ideas Utilization of math and design tools and software	Usage of prior knowledge in math and prior experiences Display of organizational techniques Communication of mathematical ideas Utilization of math and design tools and software	Usage of prior knowledge about quadratic equations and factoring Self-motivation Display of organizational techniques Communication of mathematical ideas Utilization of math and design tools and software
Monitoring progress during the accomplishment of the performance task about quadratic functions	Optimization of resources for better understanding Consideration of other sources of information	Consideration of other sources of information Usage of monitoring tools	Identification of personal strategy Situational awareness Optimization of resources for better understanding Usage of monitoring tools
Evaluating performance and output after the accomplishment of the performance task about quadratic functions	Display of fulfillment Recognition of new strategies	Display of fulfillment Recognition of new strategies	Display of fulfillment

Improving self-knowledge in accomplishing Math tasks	Show of difficulty in math concepts Display of effort	Self-actualization Show of difficulty in math concepts Recognition of shortcomings to math tasks	Show of difficulty in math concepts Display of self-confidence towards math
Improvement of mathematical performance	Acknowledgment of self-check tasks to monitor progress	Acknowledgment of self-check tasks to monitor progress and assess feelings	Consideration of peers' mathematical improvement Recognition of the importance of the task for personal and academic growth Acknowledgment of self-check tasks to monitor progress

Table 6. Themes Emerged from the Three Groups' Significant Codes about Accomplishing the Performance-Based Assessment with Metacognitive Prompts about Quadratic Functions

First, all groups demonstrated strong planning skills, leveraging prior knowledge and seeking inspiration online to enhance their performance task on quadratic functions. For instance, one student from the average group shared, *"I looked for business ideas online to help me think of a product."* This proactive approach to planning was echoed by a student from the above-average group who said, *"Before I started, I divided the work based on what I know."* Even students in the below-average group showed evidence of intentional planning, as one mentioned*, "I recalled our lesson last quarter, and I used it to start making my plan."* While organizational techniques were mainly observed in the average and above-average groups, all groups effectively communicated math and business ideas, utilizing various tools and software.

Second, students showcased monitoring skills, optimizing resources such as videos and seeking external assistance to understand concepts. A student from the average group said, *"When we got confused, we asked our teacher and even watched extra videos about quadratic functions."* Even in the below-average group, persistence was observed, as one student said, *"I didn't understand it at first, but I kept watching the video until I got it."* The above-average group stood out for openly sharing their experiences and adapting to various factors during the task, showing situational awareness and personal initiative. As one reflected, *"I changed my product idea halfway because it didn't make sense mathematically."* Both average and below average students used monitoring tools as one student from the average group shared, "*I tracked which parts I already finished and what still needed checking.",* and one student from the above average group shared, *"I used the monitoring form."*

Third, students displayed evaluative skills, showing a sense of fulfillment despite setbacks. A student from the below-average group said, *"I was proud even if I didn't get all right (sic). I still tried my best."* In addition, both below-average and average groups recognized areas for improvement. One student from the average group said, *"I could have improved my design, but I think I got the math right."* Meanwhile the above-average group demonstrated confidence in their output with one stating, *"I think I did great."*

Fourth, students demonstrated self-awareness, with the below-average group showing effort to understand complex concepts as one stated, "*I knew I was having a hard time with factoring, so I focused more on that part,"* while the average group recognized potential areas for improvement as one stated, *"I realized I need to work on organizing my proposal better next time."* The above-average group also displayed confidence in their abilities, reflecting in the quality of their output. As one student expressed, *"I feel confident because I understood both the math and the business part. The checklist really helped."* They recognized the importance of monitoring progress and expressed a willingness to utilize metacognitive strategies for continuous improvement.

Lastly, all groups recognized the value of metacognitive prompts in monitoring progress and regulating emotions. The average group recognized the emotional impact of the task, with a student sharing, *"The checklist made me reflect not just on my answers but how I felt while doing the task."*The above-average group particularly appreciated the authentic task for personal and academic growth as one student shared,*"I liked this project because it felt real. It helped me grow, not just in math but also in how I plan and solve problems."* They also acknowledged its potential to enhance mathematical performance in others where students acknowledged the broader significance of metacognitive skills for their peers, emphasizing its role in fostering academic growth and success.

DISCUSSION

Can Performance-based Assessments with the Metacognitive Prompts in Quadratic Functions Using the RME Approach Contribute to Students' Metacognitive Awareness, Skills and Overall Mathematical Performance?

We initially tested all 30 students and obtained results that support the soundness of our method. The findings revealed a significant increase in students' metacognitive awareness, especially in *Knowledge about Cognition*, which includes declarative, procedural, and conditional knowledge. Notably, *Conditional Knowledge* showed the greatest improvement, indicating enhanced critical thinking and the ability to apply strategies appropriately in solving quadratic function tasks. *Procedural Knowledge* also showed strong gains, reflecting improved strategy application through exploration, collaboration, and problem-solving activities. Though smaller in effect, *Declarative Knowledge* still demonstrated meaningful growth, showing students' improved awareness of how they learn and process information.

The intervention also positively impacted students' *Regulation of Cognition*, particularly in planning, monitoring, and evaluating their learning processes. *Planning* had the strongest effect, likely due to guided tasks and self-check questions that helped students set goals and select effective strategies. *Monitoring* and *Evaluating* improved moderately; students reported using self-check tools to track progress and reflect on performance.

Overall, the study highlights how performance-based interventions can effectively develop metacognitive skills, enabling students to better plan, monitor, and evaluate their learning—critical abilities for academic success and lifelong learning.

How Do Students Perceive the Completion of a Performance-based Assessment with Metacognitive Prompts in Mathematics, and What is Their Perceived Impact on Learning Outcomes?

Based on predetermined criteria related to their academic standing, we then selected 9 participants for further analysis. The following results were obtained from this subgroup. Students demonstrated strong planning skills in completing the performance task on quadratic functions.

While all groups effectively applied prior knowledge, only the below-average and average groups explicitly connected it to other subjects. Mathematical and business ideas were clearly communicated, with the average and above-average groups exhibiting better organization; the latter also showed initiative by seeking online inspiration.

In terms of monitoring, all groups managed resources well, with the above-average group notably adapting to challenges and reflecting on their experiences. Evaluation skills were evident across groups, with students identifying areas for improvement. The above-average group relied confidently on existing strategies, as reflected in their high-quality outputs. Self-awareness was also observed in all groups. The below-average group made notable efforts to understand complex concepts, the average group acknowledged areas for growth, and the above-average group exhibited confidence aligned with their performance.

Metacognitive prompts were seen as valuable in supporting progress and emotional regulation. The above-average group particularly appreciated the task's authenticity and relevance to real-world learning. Overall, the integration of metacognitive prompts in performance-based tasks effectively enhanced students' awareness, regulation, and academic performance.

CONCLUSIONS

Despite mandates to incorporate performance tasks as part of formative and summative assessments, many Philippine classrooms still rely heavily on procedural instruction that limits students' opportunities to apply mathematical concepts to real-life contexts. This results in limited opportunities for students to engage with authentic mathematical tasks, apply concepts meaningfully, or reflect deeply on their own learning processes. The findings of this study directly respond to this gap by demonstrating the effectiveness of integrating RME with metacognitive prompts in a performance task setting, particularly in teaching quadratic functions.

The improvements observed in students' metacognitive awareness—including gains in declarative, procedural, and conditional knowledge, as well as planning, monitoring, and evaluating skills—support previous research in the field, such as Ozdemir et al. (2020), which found a strong link between metacognitive awareness and academic resilience in mathematics.

Moreover, the qualitative insights from this study reinforce earlier conclusions by Winarso (2018) and Fauziah et al. (2018), who highlighted that context-rich, real-world tasks and mini-projects encourage not only cognitive growth but also emotional engagement and motivation. Similar to findings in Setiawan and Supiandi (2018), students in this study exhibited proactive behaviors such as thoughtful planning and self-monitoring, suggesting that structured support for metacognition cultivates independence and confidence in mathematical problem-solving.

By integrating metacognitive prompts into performance-based tasks, this study extends current understanding of how assessment can be both formative and reflective, moving beyond a one-size-fits-all approach. The intervention's differentiated effects—stronger gains in knowledge and planning, with more moderate growth in monitoring and evaluating.

The contribution of this study lies in its demonstration of a holistic, reflective assessment design that supports diverse learners in a real-world educational context. It not only validates established pedagogical frameworks but also provides practical applications relevant to local classrooms—especially where resources are limited. The study also suggests future directions for innovation in instructional design, particularly in exploring the potential of self-assessment, peer collaboration, and digital integration to further support metacognitive development. Ultimately, this research highlights that fostering metacognition through authentic, reflective performance tasks can transform mathematics classrooms—not just improving academic outcomes, but also nurturing self-directed learners prepared for lifelong learning.

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APPENDICES

Appendix A: Sample Output

BUSINESS PROPOSAL

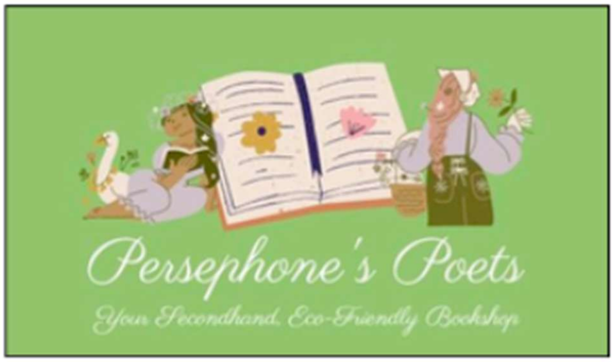
Business Name:

Persephone's Poets – Your Secondhand, Eco-Friendly Bookshop

Business Slogan:

"Let The People Read Books With Affordability & Environmental Purity!"

Business Logo

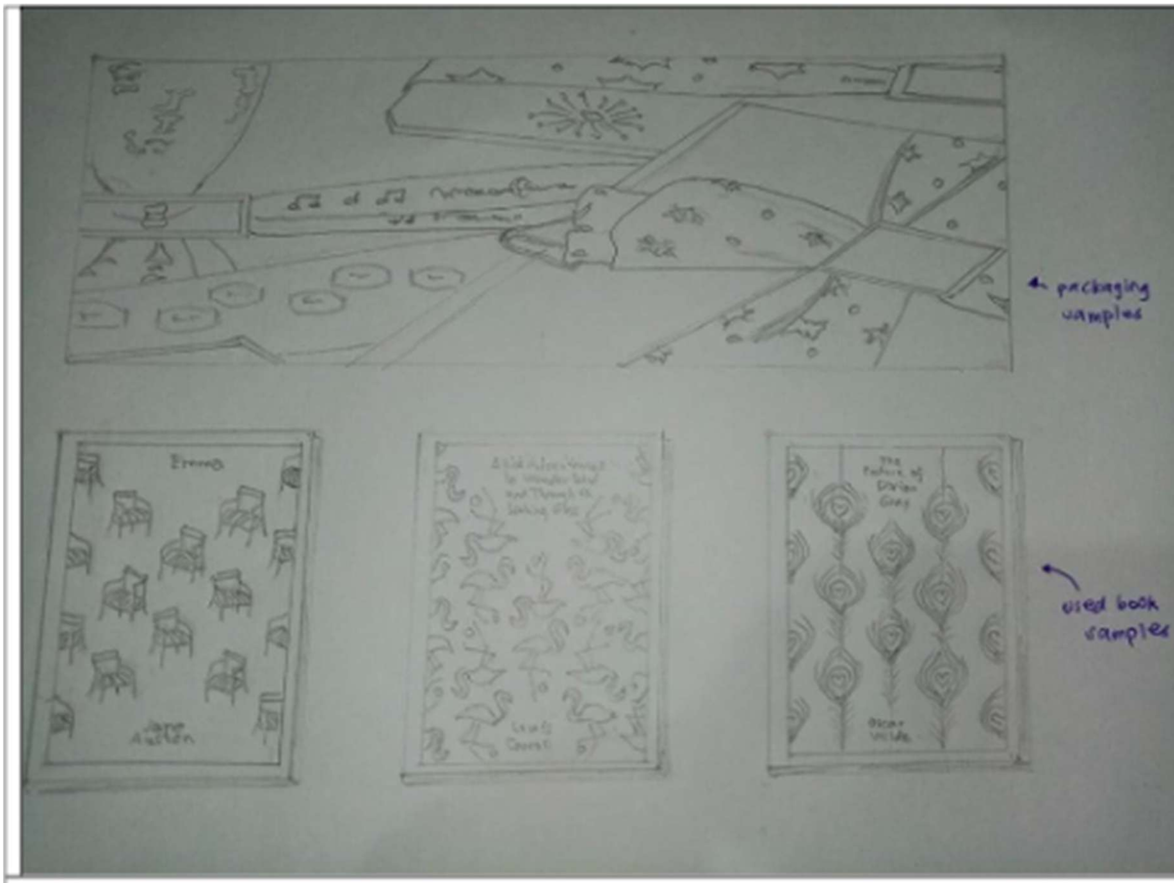


With our whimsical logo, Persephone's Poets aims to send out a warm, comforting message to our buyers that even the simplest things in life can be enjoyed and treasured. As homage to the Greek goddess Persephone, our bookshop's namesake, we chose to give an emphasis on the color green and the calm life in the countryside, hoping that the meek little books we sell would, in a special way, transport readers to cozier and happier places during tough times.

Product:

Packages that consist of three used books of satisfactory quality with genres that randomly range between literary classics, poetry, contemporaries, thrillers, etc. Every package comes with reusable, eco-friendly wrappers.

Sample of Product



Initial Selling Price: Php 100

Sales in a Month

Based on the results of my given survey, a total of 210 used book packages would be sold within a month.

Increased Selling Price: Php 120

Before increasing the selling price, I've already anticipated that there would be a significant decrease in sales. Hence, for every Php 20 increase, I would sell 14 *less* used book packages.

Revenue Maximization

a.)

- No. of Items Sold: 210
- Price per Item: Php 100
- Price Increase: Php 20
- No. of Items Sold: 14 Less (Price Inc)

* Revenue: $(210)(100) = 21,000$ ← Initial Revenue

* Maximum Revenue: $(210-14x)(100+20x)$

$$= 21000 + 4200x - 1400x - 280x^2$$
$$= -280x^2 + 2800x + 21000$$

- $-280x^2 + 2800x + 21,000$

$$= -280(x^2 - 10x + 25) + 21,000 + 7000$$
$$= -280(x-5)^2 + 28,000$$
$$= \boxed{y = -280(x-5)^2 + 28,000 \quad x = 5}$$

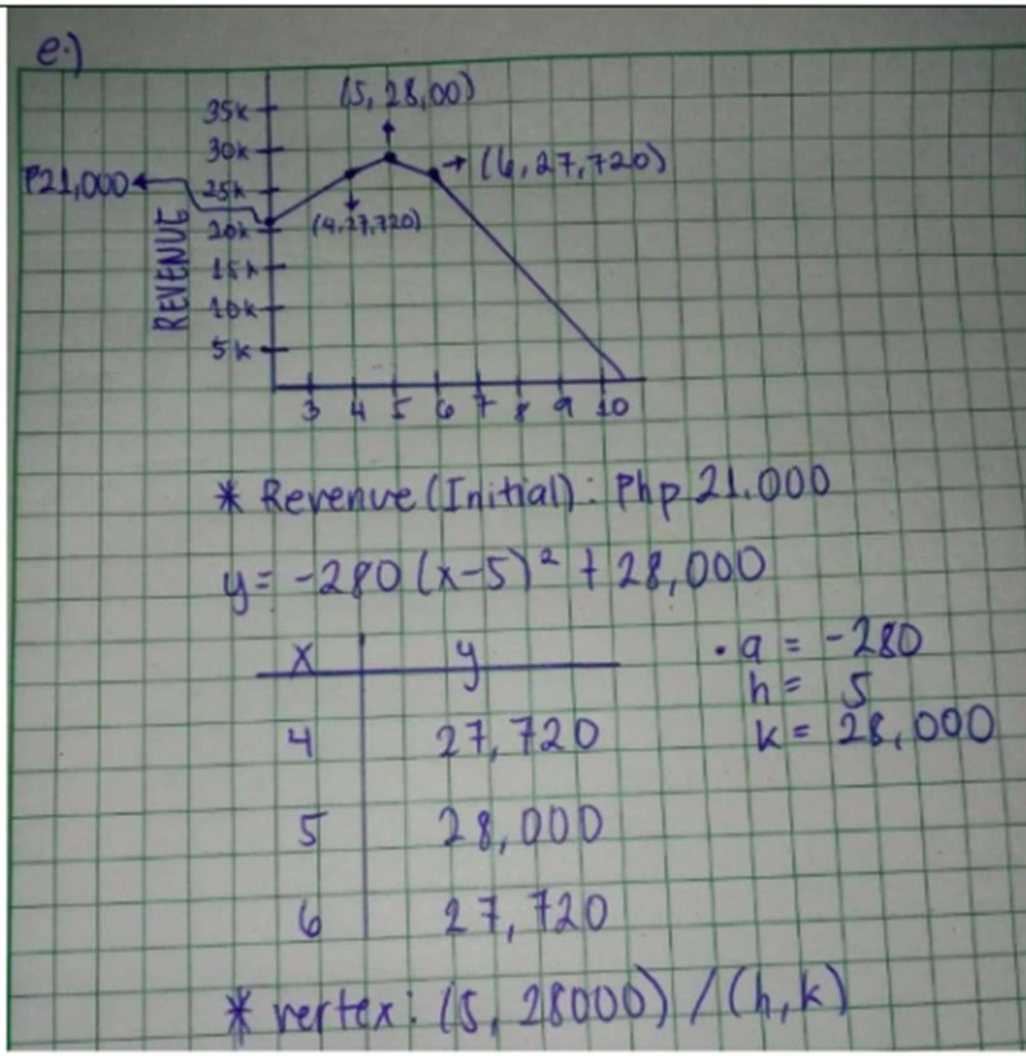
b.) * Maximum Price: $100 + 20x$

$$= 100 + 20(5)$$
$$= 100 + 100$$
$$= \boxed{\text{Php } 200}$$

c.) * Maximum No. of Itemc: $210 - 14x$

$$= 210 - 14(5)$$
$$= 210 - 70$$
$$= \boxed{140}$$

d.) * Maximum Revenue: $(140)(200) = \boxed{\text{Php } 28,000}$



Final Pricing

The final price of my product is Php 200.

Marketing Strategies

While in the middle of a pandemic, I personally think that it would be best to use social media platforms like Facebook and Instagram to promote my product. Posting eye-catching photos and promising descriptions would definitely attract more buyers and put my business out in the open. Of course, when it comes to the actual selling, there are always portable online stores such as Shopee and Lazada to use that make online selling much easier and hassle-free.

• *No, I am not struggling with the task but the solving parts are quite challenging.*
5. Should I adjust my strategies in accomplishing this task? • *I don't think adjusting my strategies is needed. They're working out fine for me.*
6. Which confusions remain and how am I going to get them clarified? • *Confusion with the "getting the vertex form" part is high at the moment. Reviewing the given materials would probably help me to get them clarified.*
7. Should I change what I planned to do? • *No, changes aren't needed since the overall plan is working like a charm.*
AFTER
1. How well did I do? • *I could confidently say that I've done well, in fact, better than I had expected.*
2. Did I get the results I expected? • *Some of the results were predicted quickly but the survey ones were quite unexpected.*
3. Is there anything I did not understand? • *I didn't understand some of the concepts in creating the graph at first but I managed to cope by eagerly reviewing the given materials about it.*
4. Do I need to go back through the task to fill in any gaps in my understanding? • *No, there aren't any gaps to fill in neither this task nor my understanding.*
5. What could I have done differently? • *There's nothing I would change since I'm highly interested and invested on the plan I've made.*
6. Can I apply the strategies I used to other problems or situations? • *Definitely, the strategies I've used are flexible routines that can be applied to almost anything.*

SELF-CHECK. Answer the following questions before, during, and after accomplishing the performance task:

BEFORE
1. What am I supposed to do? • *I am supposed to think of a specific business plan based on my own interests that I would like to carry out professionally.*
2. What resources can I use to accomplish this task? • *Articles from online business owners themselves, blogs that give useful tips, and informative YouTube videos are the resources I can use to accomplish this task.*
3. What prior knowledge will help me with this task? • *Past activities that involved entrepreneurship and culminating from my earlier high school and elementary years were solid training grounds for me and other students alike to get a good grasp on how businesses work. Aside from that, personal stories from family members and friends who are familiar with these certain activities also gave me adequate understanding.*
4. What strategies will I use to accomplish this task? • *Finishing this as aptly as I can and following a healthy schedule are the strategies I'm planning to use to accomplish this task.*
5. What should I do first? • *Before anything else, I would consider thinking of a proper business venture first. The brand name, products I would sell, and all-around theme or message I'm trying to give the public should be my kick-starters for this task.*
6. Will I be able to accomplish this task within the given time? • *Yes, I expect to finish this task in three days.*
DURING
1. How am I doing? • *Matters are sailing through smoothly though I am a bit intimated by the parts involving equation solving.*
2. Am I being systematic in accomplishing this task? • *Yes, the tasks needed to be done for each day are being thoroughly completed.*
3. Am I maximizing the use of all the resources available? • *Yes, almost all of the resources are in good use.*
4. Am I struggling with this task? If yes, which part?

Appendix B: Scores and Feedback

Create Your Own Business RUBRIC

Dimension	Weight	Mastered (3)	Working towards Mastery (2)	Needs Improvement (1)	Score
Defining the Situation	x3	Demonstrates the ability to construct clear and insightful business proposal with evidence of all relevant contextual factors.	Demonstrates the ability to construct a story line and problems with evidence of all relevant contextual factors and the proposal is adequately detailed.	Begins to demonstrate the ability to construct a story line and problems with evidence of most relevant contextual factors, but the proposal is superficial.	9
Identifying and monitoring appropriate Strategies	x3	Identifies multiple approaches for solving the problems that apply within a specific context.	Identifies multiple approaches for solving the problems, only some of which apply within a specific context.	Identifies only a single approach for solving the problems that does apply within a specific context.	9
Implement-ing Solution	x3	Implements the solution that addresses thoroughly and deeply multiple contextual factors of the problems.	Implements the solution in a manner that addresses multiple contextual factors of the problems in a surface manner.	Implements the solution in a manner that addresses the problems in the proposal but ignores relevant contextual factors.	9
				TOTAL	27

Teacher's Feedback:

Planning *(Defining the situation)*	All the needed information is evident and clear including the name, slogan, logo, product, and data obtained from pre- and post-surveys. Used helpful resources and knowledge in planning the business proposal Overall, the planning stage was clear and systematized.

Monitoring *(Identifying appropriate strategies))*	Mindful thinking and decision making if strategies are needed to be adjusted took place to resolve challenges that have been experienced Done the tasks that were previously scheduled Maximized all the resources available Overall, the way that the performance task was answered reflected to the answers on the self-check.
Evaluating *(Implementing solution)*	It is clear that the plan was created with confidence and knowledge. Overall, the mathematical component of the performance task is correct and the goal was properly demonstrated.

Appendix C. Junior Metacognitive Awareness Inventory (Jr. MAI)

Read the following sentences carefully and check the box for each answer that applies to you and the way you work on a performance task in Mathematics. Please be as honest as possible in your answers.

1 – Never 2 – Seldom 3 – Sometimes 4 – Often 5 – Always

	1	2	3	4	5
1. I am a good judge of how well I understand something.					
2. I can motivate myself to learn when I need to.					
3. I try to use strategies that have worked in the past.					
4. I know what the teacher expects me to learn.					
5. I learn best when I know something about the topic.					
6. I draw pictures or diagram to help me understand while learning.					
7. I ask myself if I learned as much as I could have once I finish a task.					
8. I ask myself if I have considered all options when solving a problem.					
9. I think about what I really need to learn before I begin a task.					
10. I ask myself questions about how well I am doing while I am learning something new.					
11. I focus on the meaning and significance of new information.					
12. I learn more when I am interested in the topic.					
13. I use my intellectual strengths to compensate for my weaknesses.					
14. I have control over how well I learn.					
15. I asked myself periodically if I am meeting my goals.					
16. I find myself using helpful learning strategies automatically.					
17. I ask myself if there was an easier way to do things after I finish a task.					
18. I set specific goals before I begin a task.					