Writing and Mathematics Acquisition: Can They Be Allies?

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ABSTRACT

This study integrated well-designed writing assignments in the three Analytic Geometry classes of a single teacher and assessed the mathematics learning of the participants (n = 57). Marginal notes, journaling, concept maps using Frayer model, and cognitive academic language learning approach (CALLA) were used as the writing activities. Mean test scores before and after the writing activities were compared. The average of the preliminary and midterm exams was encoded as the before score while that of the prefinal and final exams comprised the after score. Utilizing SPSS Version 20 and one-tailed paired-sample t-test at $\alpha = 0.05$, the results ($p = 0.000$) revealed a significant increase in math test scores mean which is moderately attributed to the writing intervention ($d = 0.5027$). A significant increase in the test scores homogeneity was also observed. Well-designed writing activities seem to enhance the acquisition of mathematics and can be an effective supplement to traditional lecture math class.

Keywords: cognitive academic language learning approach (CALLA), inscription, learning approach, mathematics achievement, metacognition

INTRODUCTION

Across countries, science, technology, and mathematics (STM) have become an essential part of basic education because there seems to be a link between the number of STM-related research personnel and the affluence of a nation. Sadly, the Global Competitiveness Report in 2011- 2012 revealed that the Philippines ranked 115th from 142 countries in terms of science and math education (Torregoza, 2014) which prompted the government to focus on elevating the quality of STM education in the country. In various developing countries like the Philippines, obtaining an education is seen as an avenue for self-improvement because of the better opportunities it offers. Despite its pervasive presence across disciplines, it is common knowledge that Mathematics is considered by most students to be a complex subject leading to a negative attitude towards Math resulting in poor acquisition.

Research has revealed that academic achievement is associated with a higher level of metacognitive awareness and learners who are metacognitively aware use more efficient specific learning strategies and attain higher performances (Kallay, 2012). In school, it means that students understand their own learning, how they learn, how they learn best, and how they learn less effectively (Cohen, Manion, & Morrrison, 2004). Since metacognitive strategies can be clearly defined and be made accessible to students, metacognition can be taught which would empower students to surpass their own learning process (Henter & Indreica, 2014). Having better metacognitive skills can help students absorb better in a learning environment (Roll et al., 2007).

Metacognition is enhanced by deep learning and it can be deliberately developed through a variety of means, one of which is to require students to reflect on their own learning (Cohen et al., 2004) through writing for as Zinsser (2013) posited, to write is to learn. Reflective journal writing is touted to nurture qualities of a critical thinker and promote thoughtful practice (Fakude & Bruce, 2003) and students who are made to write about their mathematical solving processes, are believed to show evidence of metacognitive framework (Crannel, 2002).

Incorporating writing in mathematics is posited to increase student achievement (Harlan, 2018); assessment scores and use of math vocabulary of students were found to increase after math journaling for five weeks (Kostos & Shin, 2010). Writing to learn is a strategy that can be employed throughout to help students be engaged and develop huge ideas and concepts; it nurtures critical thinking for it requires analysis, application, and other higher level thinking skills (Michigan Department of Education, 2009). Concept mapping enables direct observation of tangible measures of learning and can be utilized to track changes in the course of learning (Hay, 2007) and transforms abstract knowledge into concrete visual images (Hay, Kinchin, Lygo-Baker, 2008). The Cognitive Academic Language Learning Approach (CALLA) integrates content, language, and learning strategies and is found useful in improving learning outcomes (Gu, 2018) while marginal notes are claimed to activate students' background knowledge, enable students to check their comprehension of the text, stimulate questioning and analysis of content and most importantly, help students become aware of relevant links between text and their own thinking (Michigan Council for Teachers of Mathematics, 2005).

Most previous studies explore strategies in teaching Math but few were conducted to investigate the use of writing in math classes. As a step to address the challenge of elevating the quality of education in the country, the author believes that integrating writing activities in the teaching of mathematics will help students in its acquisition, thus, the primary purpose of the study was to determine if well-designed writing activities, which were intentionally made to suit topics on conics, improve mathematics acquisition. The study uses the writing to learn approach as the framework which is based on the opinion that students' ideas and understanding can be nurtured and clarified through writing (Bazerman et al. 2005). The approach which is included in the Writing Across the Curriculum program and movement was employed to determine the objective of the study: Do writing activities improve mathematics acquisition? The writing activities included in the study are marginal noting, journaling, concept mapping using Frayer model, and Cognitive Academic Language Learning Approach (CALLA).

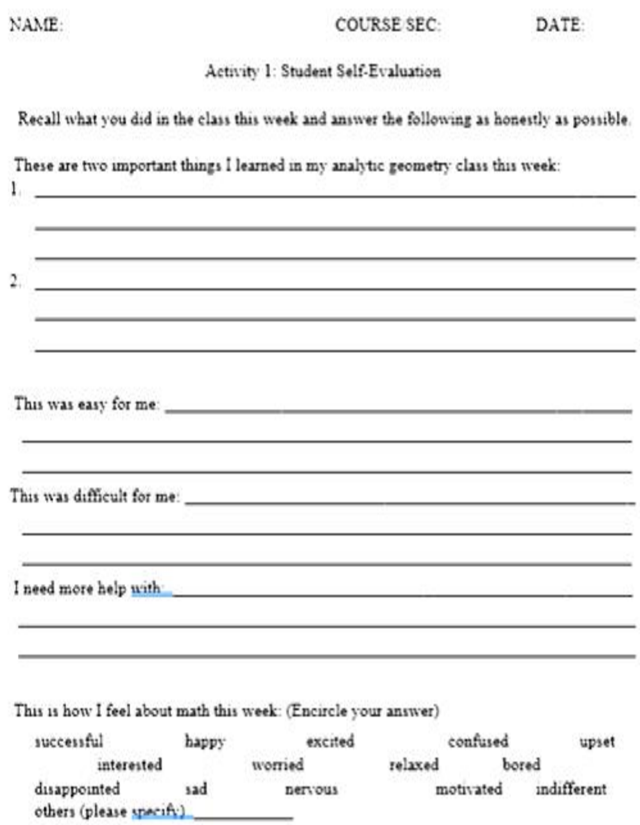
METHODOLOGY

The study employed a quasi-experimental design. Three intact classes (n = 57) of a single teacher during the 1st semester of AY 2016-2017 were used as participants to determine if well-designed writing activities improve mathematics acquisition; well-designed means intentionally made (in this case for Analytic Geometry class specifically on the topic conics). Four different types of writing assignments, which were not graded, were administered to supplement the traditional lecture class. The writing activities were intended to foster critical thinking requiring analysis, application and other higher order thinking skills.

Traditional lecture method was used from the start of the classes until the midterm period where during this time two long exams (prelim and midterm) were administered. Right after the conduct of the midterm exam, 9 different writing activities which were not graded were given as assignments to supplement the traditional lecture class; during this period, the participants also had two long exams, pre-final and final exam. The test scores of the participants before and after the implementation of the 9 writing activities (computed as score of a participant divided by the perfect score) were compared. The average score of the preliminary and midterm exams was labeled as the score before while the average score for the prefinal exam and the final exam comprised the after score. A significant test of difference was determined using a one-tailed paired-sample t-test employing SPSS version 20 while Cohen's d was used to determine the effect size.

Designed and developed to be appropriate about conics, the writing activities used were marginal notes, journaling, concept mapping, and cognitive academic language learning (CALLA) approach. Journaling requires students to keep a record of their experiences over a period of time allowing them to make reflections of their experiences. Journaling allows students to reflect on anything they find relevant (Urquhart, 2009). Journaling for a week allowed students to become conscious of their math experiences in class. Writing activity # 1 (Fig. 1), a product of journaling, is a student self- evaluation about the week's math experience; it is an open-ended questionnaire which identifies the two most important lessons of the week and which part was the easiest and the hardest. It also requires the participants to describe how they felt about the math lesson. Their self-evaluation of these experiences became writing activity # 1.

The concept mapping patterned after the Frayer model, which uses a graphic organizer, is designed to help students understand the concept (Buehl, 2001). Writing activities 2, 3, 5, and 6 used Frayer models (Fig. 2) which helped students organize their ideas on circle, parabola, ellipse, and hyperbola. The purpose of the Frayer model, is to define unfamiliar concepts and vocabulary. This is done on a chart divided into four sections to provide a visual presentation of the concept. The model organizes prior knowledge about a concept or mathematical term graphically: it gives operational definition, characteristics, examples, and non-examples. Writing activities # 2, 3, 5, and 6 are concept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Activity 1: Student Self-Evaluation

Recall what you did in the class this week and answer the following as honestly as possible.

These are two important things I learned in my analytic geometry class this week:

1. ________

2. ________

This was easy for me: ________

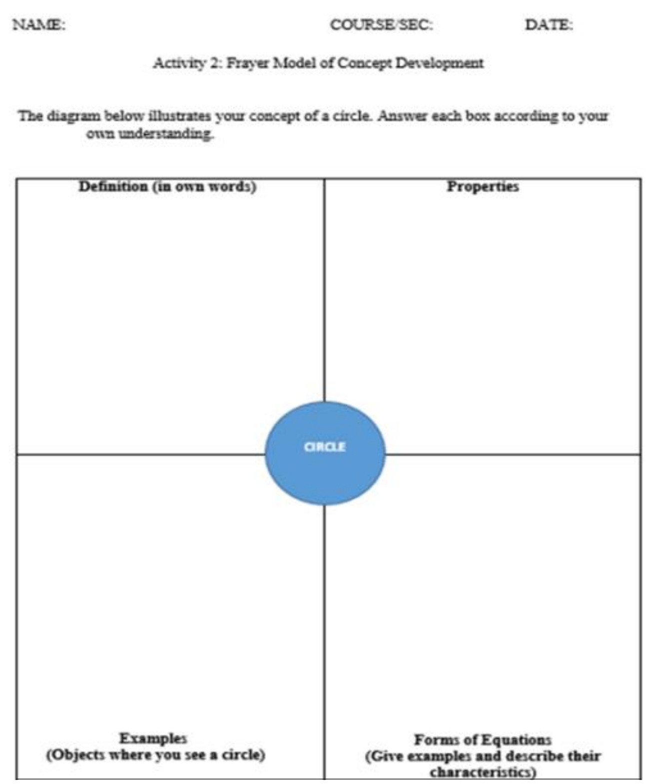
This was difficult for me: ________

I need more help with: ________

This is how I feel about math this week: (Encircle your answer)

successful happy excited confused upset interested worried relaxed bored disappointed sad nervous motivated indifferent others (please specify) ________

Figure 1. Writing activity #1 is a product of journaling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Activity 2: Frayer Model of Concept Development

The diagram below illustrates your concept of a circle. Answer each box according to your own understanding.

Figure 2. Writing activity #2, Frayer model of concept mapping

maps of circle, parabola, ellipse, and hyperbola respectively. Participants were asked to define the four conics, give their properties and equations, and identify objects where circles, parabolas, ellipses, and hyperbolas are exhibited.

Marginal notes are short written statements in which students record their interactions with the text in the margins while they are reading (Michigan Dept. of Education, 2009). Writing activity # 4 (Fig. 3) is a marginal note on quadratic equations representing conics. Here, participants described the step-by-step process of how they solved a specific equation of a circle and an equation of a parabola patterned after a writing prompt. Each step is described on a column opposite the equations.

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Activity 4: Marginal Notes

Example:

Factor this quadratic:	Student response:
$x^2 + 6x + 8$	I have to think about how to solve this quadratic.
$x^2 + 4x + 2x + 8$	I don't know where the 4x and 2x came from.
$x(x+4) + 2(x+4)$	It looks like x is factored from the first two terms and 2 was factored from the last two terms.
$(x+4)(x+2)$	I don't know how an addition problem became a multiplication problem.

Using marginal notes, solve the two problems below.

Include the step-by-step process of your solution on the left and indicate the student response on the right. Write your answer at the back. Use additional sheets if necessary.

Find the equation of the circle having (8,1) and (4, -3) as ends of a diameter	Student response

Find the equation of the parabola with vertex at V(2, 5) and focus at F(2, 3)	Student response

Figure 3. Marginal noting is utilized in writing activity # 4

The CALLA strategy is a process where students are guided to a solution to a problem and writing what makes the problem difficult and how are they able to solve the problem. Writing activities # 7 (Fig. 4) and 8 are CALLA on ellipse and hyperbola. The strategy is very similar to marginal notes but requires participants to answer open-ended questions at the end.

NAME: COURSE/SEC: DATE:

Activity 7: Cognitive Academic Language Learning Approach (CALLA) - Ellipse

Show a step-by-step solution together with an explanation for each step as you find the equation of an ellipse with center (-2, 2), vertex (- 6, 2), one end of minor axis (-2, 0).

Given: C(-2, 2), V(- 6, 2), one end of minor axis (- 2, 0)

Required: Equation of the ellipse

Solution: (You may add rows/columns when necessary)

Step	Explanation

Questions:

1. Which step was the easiest? Why was it the easiest?
2. Which step was the hardest? Why was it the hardest?
3. Is there a step which confused you? How did you address your confusion?

Figure 4. Writing activity # 7 - Cognitive Academic Language Learning Approach (CALLA)

The last writing activity (writing activity # 9) is a table of comparison and contrast of the four conics: circle, parabola, ellipse, and hyperbola. Writing activity # 9 is a culmination of the learning on conics as students filled out a table of comparison and contrast of circle, parabola, ellipse, and hyperbola. This required the participants to explain the general equation, standard form, and properties of the conics.

RESULTS AND DISCUSSION

Writing- To- Learn

It is a common knowledge that communication plays an essential role in developing understanding as it takes various forms which include oral and written endeavors. Graham and Hebert (2011) presented evidence that writing about a material read improves the comprehension of students. Writing has been recognized to have a primary role in mathematical literacy (NCTM, 2000) since writing in mathematics demonstrates how well one understands mathematical ideas and concepts (Lee, 2015).

Articles on the positive impact of writing and learning abound. There exists substantial evidence that writing can be an effective tool to promote learning and engagement (Graham & Perin, 2007; Brewster & Klumpp, 2004). Bangert-Drowns, Hurley, Wilkinson (2004) argued that meta-analysis of their school-based writing-to-learn programs showed that writing can have a positive impact on achievement. Stout in 2011 shared his belief along with other learning theorists that writing and thinking are inseparable and that writing involved deliberate analytical action on the part of the producer (Vygotsky, 1987). It is not surprising then, that writing is used to better understand a discipline.

Writing in mathematics, for instance, helps students consolidate their thoughts because it requires them to reflect on their work and clarify their thoughts (Pugalee, 2001). Crannel (2002) believed that students who are made to write about their mathematical solving processes, showed evidence of metacognitive framework. Writing in mathematics helps students consolidate their thinking for it requires them to reflect on their work and clarify their thoughts as espoused by the National Council of Teachers of Mathematics (NCTM) in 2010. The Council acknowledged that writing is an important component of math instruction. This has been explicitly expressed in their Principles and Standards for School Mathematics; "written communication must be encouraged and mathematics education should empower learners to unify and associate their mathematical thinking through communication; express their mathematical thinking comprehensibly and clearly, analyze and evaluate the mathematical strategies of others, and use the language of mathematics to express mathematical ideas precisely" (p 60).

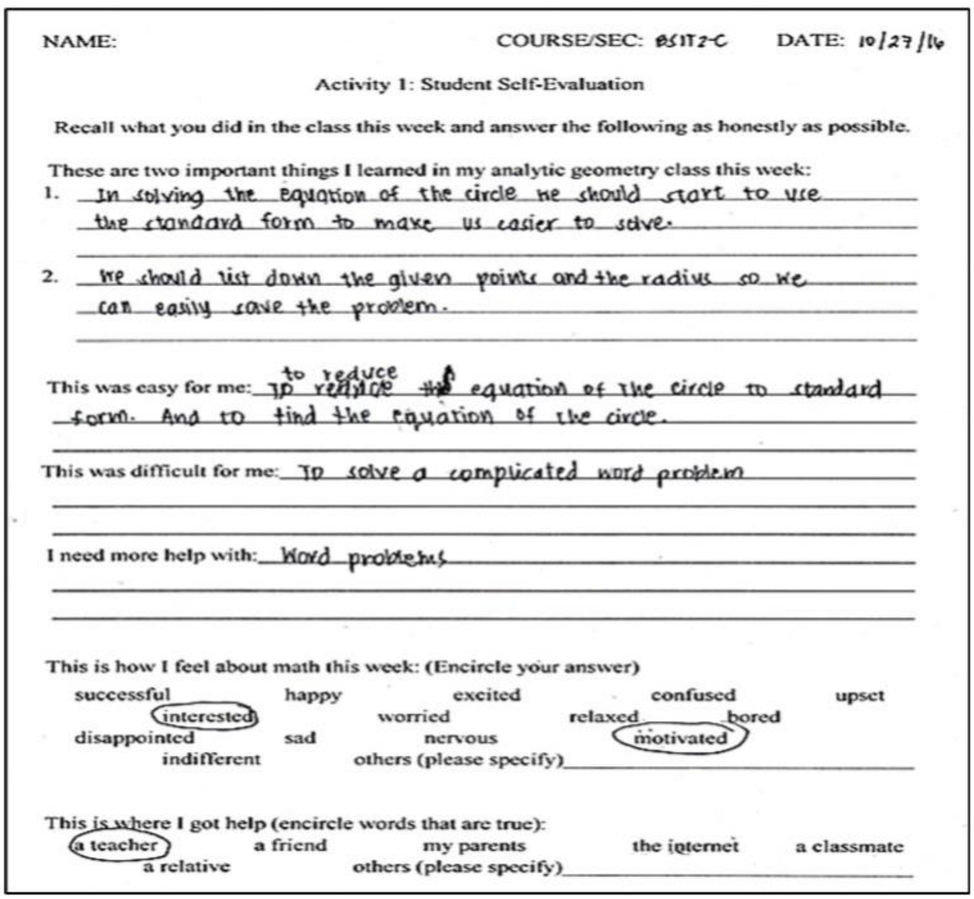
Zinsser (2013) claimed that writing is the best way to immerse oneself into a subject and own it. Requiring students to reflect on their own learning through writing is a deliberate way to develop deep learning which enhances metacognition (Cohen et al., 2004).

Metacognition, which consists of metacognitive knowledge and metacognitive experiences, refers to higher order thinking skills which involve control over the cognitive processes involved in learning (Livingston, 2003); it allows users to monitor, regulate and direct their personal cognitive strategies (Blummer & Kenton, 2014). At school, it means that students understand their own learning, how they learn, how they learn best, and how they learn less effectively (Cohen, Manion, & Morrrison, 2004). Research has revealed that academic achievement is associated with a higher level of metacognitive awareness and learners who are metacognitively aware use more efficiently specific learning strategies and attain higher performances (Kallay, 2012). Metacognition can be taught as metacognitive strategies can be clearly defined and presented to students and by teaching students metacognitive methods they are empowered to overtake their own learning process (Henter & Indreica, 2014). Having better metacognitive skills can help students learn better in a learning environment (Roll et al., 2007).

Writing Activities

Writing has been touted by many educators as a way to enhance learning for writing itself is a form of learning and it supports learning strategies (Bangert-Drowns, Hurley, and Wilkinson, 2004). A well-designed writing assignment can both engender deeper understanding because properly constructed writing assignments can aid students in making connections with a discipline (Stout, 2011). Figure 5 shows a self- evaluation which is writing activity 1. The journal writing enabled the students to realize the important lessons the previous week, how they felt about mathematics, which part was the most difficult, and who to turn to for help. The top five emotional states about mathematics during the first week were interested, motivated, worried, nervous, and confused. Most of the students sought help from their classmates, teacher, and friends. This should encourage more collaborative activities among students in the mathematics class.

Keeley and Tobey in 2011 suggested that the Frayer model can be used in determining prior understanding of students about a concept before planning a lesson as they are engaged in the learning activities and discussion, clarification on the concept can be done which can deepen their understanding of the concept. Refinements on their original understanding can also be done during discussion. In the study, students described essential characteristics of the conics and gave examples of circles, parabola, ellipse, and hyperbola. Figure 6 shows the students' understanding of parabola by using their own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Activity 1: Student Self-Evaluation

Recall what you did in the class this week and answer the following as honestly as possible.

These are two important things I learned in my analytic geometry class this week:

1. In solving the equation of the circle we should start to use the standard form to make us easier to solve.

2. We should list down the given points and the radius so we can easily solve the problem.

This was easy for me: to reduce the equation of the circle to standard form. And to find the equation of the circle.

This was difficult for me: To solve a complicated word problem

I need more help with: Word problems

This is how I feel about math this week: (Encircle your answer)

successful, happy, excited, confused, upset, interested, worried, relaxed, bored, disappointed, sad, nervous, motivated, indifferent, others (please specify)

This is where I got help (encircle words that are true):

a teacher, a friend, my parents, the internet, a classmate, a relative, others (please specify)

Figure 5. Accomplished writing activity # 1

words in the definition and providing practical examples of a parabola. The activity allowed the students to reflect on the properties of the parabola which include the directrix, focus, vertex, axis, and latus rectum. When they gave examples of objects which exhibit the parabola, they were led to imagine the curve on these objects.

On the one hand, marginal noting, writing activity 4 (Fig. 7) is observed to activate students' background knowledge, encourage analysis of a process, help students become aware of the connection between a step and the reason for that step, which improves their thinking (meta-cognition), and allow them to monitor their understanding of the process.

On the other hand, writing activities 7 (Fig. 8) and 8 made use of the CALLA on ellipse and hyperbola. Participants answered open-ended questions at the end which made the activity different from marginal noting. Reflecting on the easiest and most challenging steps allowed the students to have a better understanding of the process they went through to be able to get the equations. This teaches students to use learning strategies from a cognitive model of learning which aid in their comprehension and retention of concepts (O'Malley, 2010).

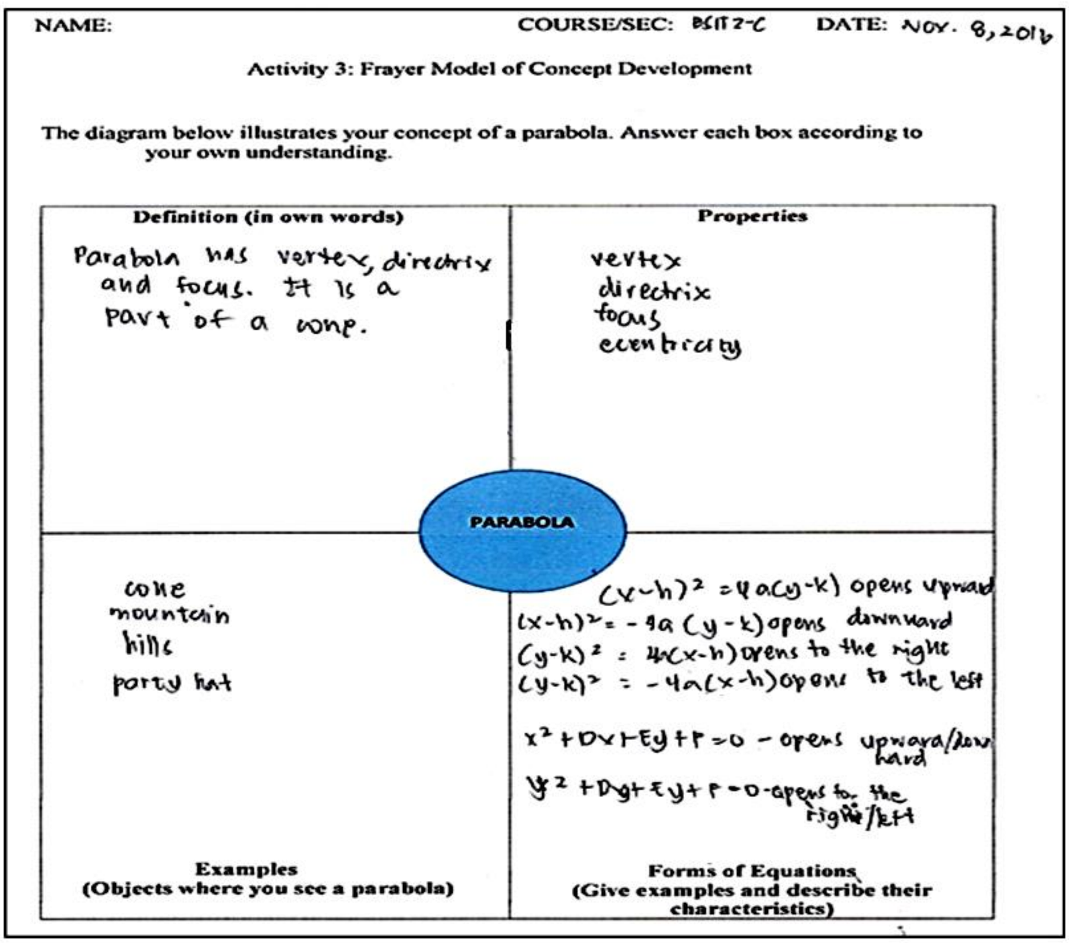
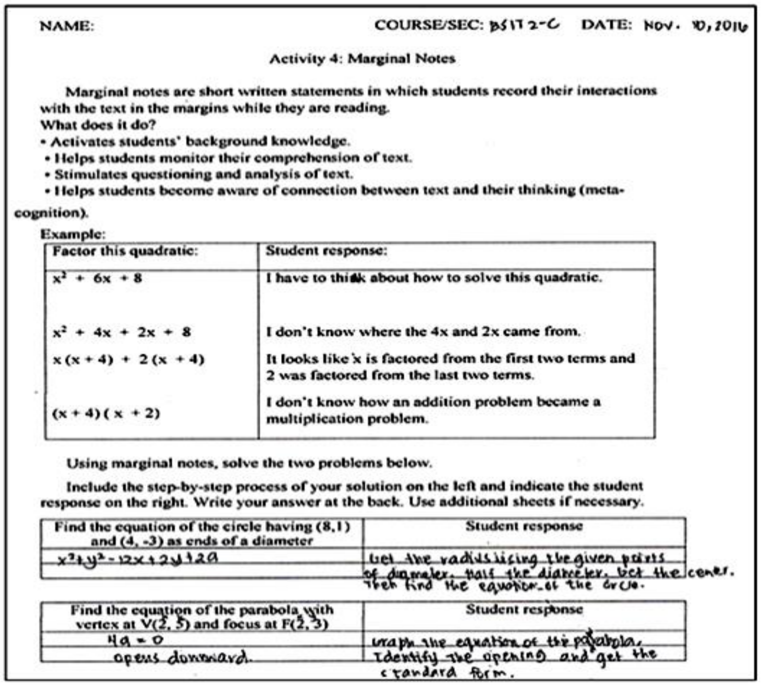


Figure 6. Concept mapping of a parabola using the Frayer model



NAME: COURSE/SEC: BSIT 2-C DATE: Nov. 10, 2016

Activity 4: Marginal Notes

Marginal notes are short written statements in which students record their interactions with the text in the margins while they are reading.

What does it do?

- Activates students' background knowledge.
- Helps students monitor their comprehension of text.
- Stimulates questioning and analysis of text.
- Helps students become aware of connection between text and their thinking (meta-cognition).

Example:

Factor this quadratic:	Student response:
$x^2 + 6x + 8$	I have to think about how to solve this quadratic.
$x^2 + 4x + 2x + 8$	I don't know where the 4x and 2x came from.
$x(x + 4) + 2(x + 4)$	It looks like x is factored from the first two terms and 2 was factored from the last two terms.
$(x + 4)(x + 2)$	I don't know how an addition problem became a multiplication problem.

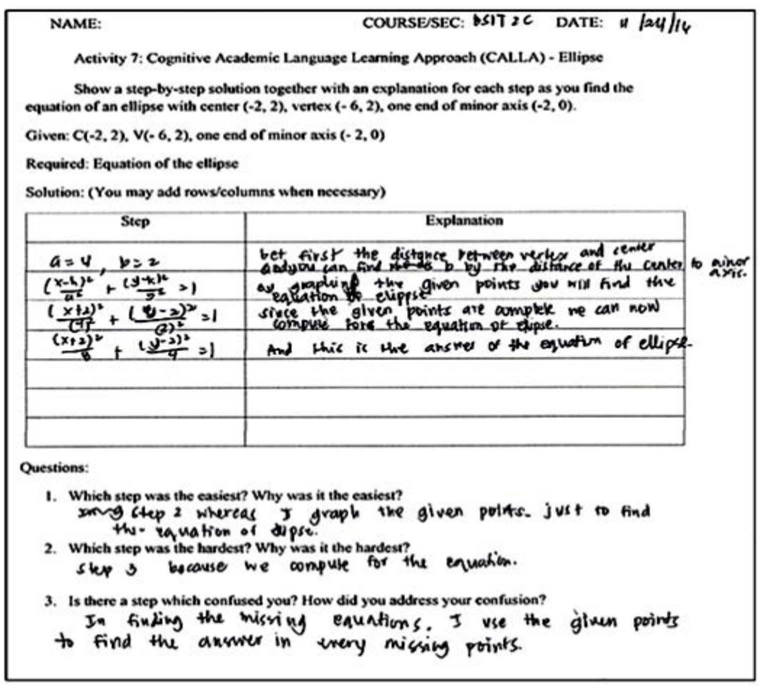
Using marginal notes, solve the two problems below.

Include the step-by-step process of your solution on the left and indicate the student response on the right. Write your answer at the back. Use additional sheets if necessary.

Find the equation of the circle having (8,1) and (4, -3) as ends of a diameter	Student response
$x^2+y^2-12x+2y+20$	Get the radius using the given points of diameter. Half the diameter. Get the center. Then find the equation of the circle.

Find the equation of the parabola with vertex at V(2, 5) and focus at F(2, 3)	Student response
4a = 0	Graph the equation of the parabola.
opens downward.	Identify the opening and get the standard form.

Figure 7. A sample output of marginal noting



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Activity 7: Cognitive Academic Language Learning Approach (CALLA) - Ellipse

Show a step-by-step solution together with an explanation for each step as you find the equation of an ellipse with center (-2, 2), vertex (- 6, 2), one end of minor axis (-2, 0).

Given: C(-2, 2), V(- 6, 2), one end of minor axis (- 2, 0)

Required: Equation of the ellipse

Solution: (You may add rows/columns when necessary)

Step	Explanation
a = 4, b = 2	Get first the distance between vertex and center and you can find b by the distance of the center to minor axis.
$\frac{(x-h)^2}{a^2} + \frac{(y-k)^2}{b^2} = 1$	by graphing the given points you will find the equation of ellipse
$\frac{(x+2)^2}{(4)^2} + \frac{(y-2)^2}{(2)^2} = 1$	since the given points are complete we can now compute for the equation of ellipse.
$\frac{(x+2)^2}{16} + \frac{(y-2)^2}{4} = 1$	And this is the answer of the equation of ellipse.

Questions:

1. Which step was the easiest? Why was it the easiest?
   Step 2 whereas I graph the given points. just to find the equation of ellipse.
2. Which step was the hardest? Why was it the hardest?
   step 3 because we compute for the equation.
3. Is there a step which confused you? How did you address your confusion?
   In finding the missing equations, I use the given points to find the answer in every missing points.

Figure 8. A sample output of marginal noting

A Test of Significance

The two test scores (prelim and midterm) constituted the test scores before the implementation of writing activities, labeled as scores before while the two test scores (prefinal and finals) comprised the test scores after the implementation of the writing activities were labeled as scores after. Table 1 shows that the mean test scores of students are significantly higher after the writing activities. The computed effect size is 0.5027 using Cohen's d.

Results of the one-tailed paired t-test at $\alpha = 0{,}05$ revealed a significant difference between the test scores of the participants before and after the implementation of the writing activities (p= 0.000). A significant increase in the test mean scores were observed ($\bar{x}_{after} = 40.6842 > \bar{x}_{before} = 33.7281$) which indicates that test scores after the implementation of the writing activities were significantly higher. The significant increase in the test scores is moderately attributed to the implementation of the writing strategies as suggested by the value of the effect size (d = 0.5027) which indicated a moderate practical significance. The magnitude of the effect renders the result on statistical significance more interesting (Sullivan & Feinn, 2012, McMillan & Foley, 2011) and though statistical significance and effect size do not substitute for each other, they complement each other (Fan & Konold, 2010).

The various writing activities apparently made the students more engaged in their learning of conics because they were able to reflect the concepts better as they write. The results indicated that students acquire a better understanding of the conics. As Dalporto (2013) asserted, writing boosts retention, enhances the depth of understanding on a subject, develops critical thinking, and stimulates independent thinking. The results support the study on the written work of three boys which revealed how their representations became more sophisticated over time (Selling, 2016). These representations served as learning practice which allowed them to be more engaged in generalizing and explaining claims and collaborate and persist in problem-solving. Structured writing assignments positively impact the performance of students on knowledge and comprehension assessment (Dynan & Cate, 2009), and individual writing allows expression, clarification, reflection, reasoning, communication of own concepts and explanations which are fruitful tools in the process of knowledge revision (Mason, 2001) and improving the writing skills of students improves their capacity to learn (National Institute for Literacy, 2007).

The standard deviation is considered to be the most useful index of variability. The computed values of the standard deviation show an improvement in the homogeneity of scores after the writing activities. The scores of the participants after the writing activities appeared to

Table 1. Paired-sample t-test at $\alpha = 0.05$ (d = 0.5027)

	Mean ($\bar{x}$)	Std. (σ) Deviation	Std. Error Mean	Sig (1-tailed)	Remark
Scores before	33.7281	18.8334	2.4946	0.000	Significant difference exists
Scores after	40.6842	12.5984	1.6687		

be closer to the mean than the scores before the writing activities which tend to be more scattered.

This shows that after the writing activities ($\sigma_{after} = 12.60 < \sigma_{before} = 18.83$) the scores were less dispersed which is a positive outcome for it indicates less disparity between the individual test scores and the mean.

CONCLUSION

Journaling, concept mapping, marginal noting, and CALLA are writing activities which seem to be an effective supplement to traditional lecture mathematics class for better math acquisition. The reflective nature of writing complements the critical and logical identity of mathematics and this blend creates a unique learning culture where writing becomes an effective tool in the acquisition of mathematics.

RECOMMENDATIONS

An in-depth study on the role of well-designed writing assignments in mathematics classes is recommended. A qualitative research is needed to find out how writing activities enhance mathematics acquisition.

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