

## What Can Writing Do in a Mathematics Class?

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### ABSTRACT

Integrating writing in a curriculum can be tasking for many but once used to it, this could be one of the best tools in demonstrating students' conceptual understanding in Mathematics. The study determined the level and the extent of development of the mathematical thinking processes in the students' journal entries and examinations in terms of conceptual knowledge, strategic knowledge, communication, and representation. A non-experimental research design was employed using mixed methods. The results showed that the longer the time the students were exposed to journal writing, the more their mathematical thinking processes were developed. Evidently, the most developed strand of mathematical thinking processes was communication and the least was representation. There were four identified benefits emerged, namely: a shift from passive to active learner; the development of mathematical thinking skills; upholding better informed future teaching, and a call for curriculum modification. It is recommended that journal writing experience can be enhanced through giving of authentic tasks that may reveal attitudes, anxieties and beliefs about mathematics that might be interfering with the students' learning.

**Keywords** :mathematics education, journal entries, mathematical thinking processes, pre-service teachers mixed methods, Davao City, Philippines

### INTRODUCTION

The National Council of Teachers of Mathematics (NCTM, 2000) Principles of Learning states that students must learn mathematics with understanding. Understanding exists when students know how to clarify and reflect on their ideas (Hiebert et. al, 2005) and when asked to explain the answer to a given mathematics problem, they can demonstrate their mathematical thinking processes (Kostos& Shin, 2010). However, teachers may lack ways to design a classroom that supports students' mathematical knowledge and manipulation of mental skills and strategies. Journal writing has become a window into the mind of the students (Goldsby&Cozza, 2002) who are engaged in mathematical activities, providing the opportunity to see the why, not just the how, of the students' thinking.

In a classroom scenario, most mathematics courses do not provide students with opportunities to practice writing in a communicative context where they feel the need to write and become confident in their abilities to communicate in writing (Williams and Wynne, 2000). Students usually do not write unless they are pressurized to do so and are given a specific topic to address. Their writing is, therefore, de-contextualized since it has no definite purpose other than completing the assignment. Aside from accomplishing assignment, another way is to give chance to students to express and expound their ideas on paper (Ibarreta and McLeod, 2004).

Journal writing can be used to examine primary students' perception and their ability to explain their understanding of multiplication and division. Result of the study conducted by Huat & Mei (2005) reveals that the use of appropriate journal writing prompts gives students the opportunity to explain their understanding and perception of mathematics learnt. The results from students' journal writing help teachers to understand their students' thinking and take the necessary measures to clarify the mathematical concepts involved in the topics of multiplication and division. Teachers can gather a lot of information about students' thinking in their writings and journal writing can be an effective and alternative way to increase teachers' understanding of their students learning in mathematics.

Dales (2005) provided an analysis on the effectiveness of the use of journal writing in a college algebra class, participated by the selected BEED students of Bukidnon State College. The quasi-experimental non-equivalent pretest-posttest control group design was used in the study. Based on the responses of the students to the journal prompts, the results showed that journal writing developed students' self confidence, encouraged them to study their lessons and made them comfortable in the learning process. The results of the ANCOVA comparison of the two achievement groups revealed that students exposed to journal writing performed better than those students not exposed to it. There was a significant difference in the achievement test results of the students in favor of the experimental group.

In the University of Mindanao Tagum Campus- Teachers College Program, writing is only integrated in portfolio assessment of students during their field studies. Just as the influence of the National Council of Teachers of Mathematics Standards has been felt dramatically in almost every aspect of the teaching of mathematics, the challenge of increasing the amount of writing done in the mathematics classrooms has been duly addressed to mathematics educators. Exposing students to journal writing has never been implemented due to content-based instruction and traditional assessment policy popularized in the whole University. There is a need to implement something new into current teaching since it is believed that to learn mathematics, students must be engaged in exploring, conjecturing, thinking and reflecting (Spikell, 1993) rather than a rote learning of rules and procedures. Mathematical communication through journal writing can encourage students to think and explain the process of solving a problem, thus they have opportunities to extend and clarify that thinking.

The main focus of this study was to determine what writing can do in a mathematics class. Specifically, to explore the use of journal writing in Analytic Geometry class in developing students' mathematical thinking processes in solving problems. This answered the following research questions: What is the profile of the participants in terms of their mathematical ability? What is the level of mathematical thinking processes in the students' journal entries in terms of conceptual knowledge; strategic knowledge; communication; and representation? What is the extent of development of mathematical thinking processes in the students' journal entries; examinations; and perceptions? What are the benefits and limitations encountered by students and teacher while integrating journal writing in Analytic Geometry class?

## METHODOLOGY

The research design employed in this study was non-experimental utilizing mixed methods. The descriptive design described the use of journal prompts in eliciting mathematical thinking processes in the students' journal entries and examinations. It utilized the quantitative method to determine the level and the extent of development of the four strands of mathematical thinking processes in terms of conceptual knowledge, strategic knowledge, communication and representation. At the same time this study utilized qualitative method. The qualitative method was used to investigate participants' and facilitator's impressions on journal writing integration, the pedagogical challenges it entailed and the difficulties which

possibly hindered its effective implementation. Specifically, questions raised to them were central to their opinions regarding the benefits, challenges and limitations encountered all throughout the duration of the study.

The setting for this study was one class in Analytic Geometry during the 2<sup>nd</sup> Term, 2<sup>nd</sup> Semester of academic year 2012-2013 at the University of Mindanao, Matina Campus, Matina, Davao City. There were 16 second year BSED-Mathematics students, 7 males and 9 females, who gave their approval to participate in this study. Though all students gave their consent to participate, only 13 were considered because the other 3 participants lacked journal entries. All the students' names reported were pseudonyms to maintain confidentiality.

A faculty member teaching Analytic Geometry facilitated the integration of journal writing in class. The whole term (approximately 8 weeks) was allotted for the conduct of the study. Meanwhile, three raters participated in this study. Raters included (1) the researcher of this present study with master of mathematics education and mathematics teaching degrees, (2) a faculty member of mathematics education with a background in authentic assessment, and (3) a research enthusiast with master in educational studies and mathematics education degrees. The raters underwent training on how the students' journal entries were assessed. Besides, inter-rater reliability was determined and found that the three raters had manifested homogeneity or consistency in their ratings.

The study utilized a number of research instruments in the data collection process namely: standardized test-questionnaire; prompts for journal entries and examinations; scoring rubric; prompts for electronic mail; self-evaluation questionnaire; focus group discussion questionnaire; final writing assignment questionnaire; and interview guide for the facilitator.

## RESULTS AND DISCUSSION

### *Profile of the Participants in terms of their Mathematical Ability*

The profile of the participants in terms of their mathematical ability is reflected in Fig. 1. This was utilized to establish baseline data in relation to the other research problems. In a 50-item standardized College Algebra test administered to the participants, result revealed that only one participant got a score within the range of 41 – 50, described as outstanding, another participant with above average (31- 40) and one participant with below average (11 – 20). Out of thirteen (13) takers, the majority have an average mathematical ability indicated by their scores within the range of 21 – 30. Computations utilizing descriptive statistics disclosed a mean of 26.9 or 27 and a standard deviation of 6.46 in an almost symmetrical or normal distribution. These results are basis to further elaborate the extent of development of the students' mathematical thinking processes when incorporating journal writing in class.

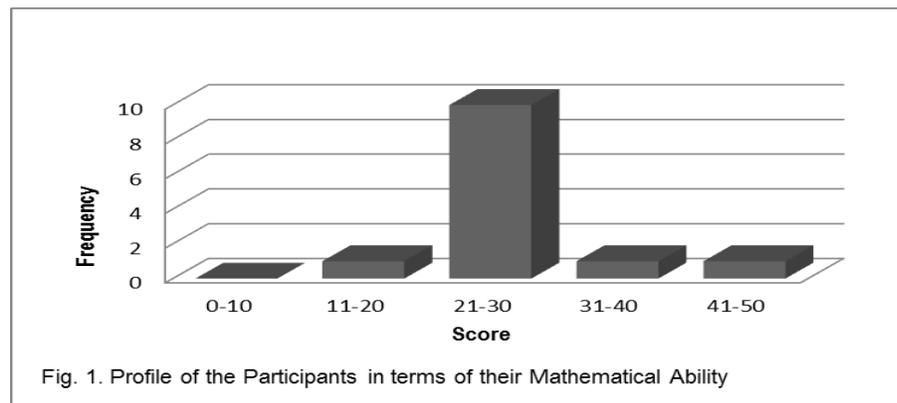


Fig. 1. Profile of the Participants in terms of their Mathematical Ability

**Mathematical Thinking Processes in the Students' Journal Entries**

Shown in Table 1 are the combined assessment results of the 3 raters on the level of mathematical thinking processes in the students' journal entries. Specific mean score for each strand and its over-all mean with the corresponding descriptive levels are disclosed in the table. Notably, the standard deviations are small and very close to each other. These small values indicate that the students' scores in their journals are very close to the computed means. The data highlight that students' exposure to journal writing has contributed in some degree an improvement on the level of mathematical thinking processes for the whole duration of journal writing implementation. For instance, in communication strand, when students' journals were assessed after two weeks of writing in class it found out that the students only provided minimal explanation of a solution process, failed to complete or omitted significant parts of the problem and explanation or description was missing or difficult to follow. After an additional of two weeks, students gave some explanation of a solution process employed though communication was still vague and difficult to interpret. Finally, at the concluding stage in about six weeks, these students wrote a fairly complete response with reasonably clear explanation and description of the solution process. It is clear that having students write about mathematics not only addresses the communication standard in the Principles and Standards for School Mathematics but writing activities also have the potential to reinforce each of the other Standards in the areas of number and operation and so with problem solving (NCTM, 2000).

**Table 1. Combined Assessment Results of the 3 Raters on the Level of Mathematical Thinking Processes in the Students' Journal Entries**

Strands	Journal Entries (Set 1)			Journal Entries (Set 2)			Journal Entries (Set 3)		
	$\bar{X}$	SD	DL	$\bar{X}$	SD	DL	$\bar{X}$	SD	DL
Conceptual Knowledge	1.83	0.40	MH	2.50	0.59	H	3.33	0.53	VH
Strategic Knowledge	1.77	0.36	MH	2.38	0.59	MH	3.15	0.55	H
Communication	0.97	0.67	L	2.05	0.78	MH	3.15	0.72	H
Representation	1.98	0.40	MH	2.35	0.48	MH	2.80	0.56	H
Over-all	1.64	0.46	MH	2.32	0.61	MH	3.11	0.59	H

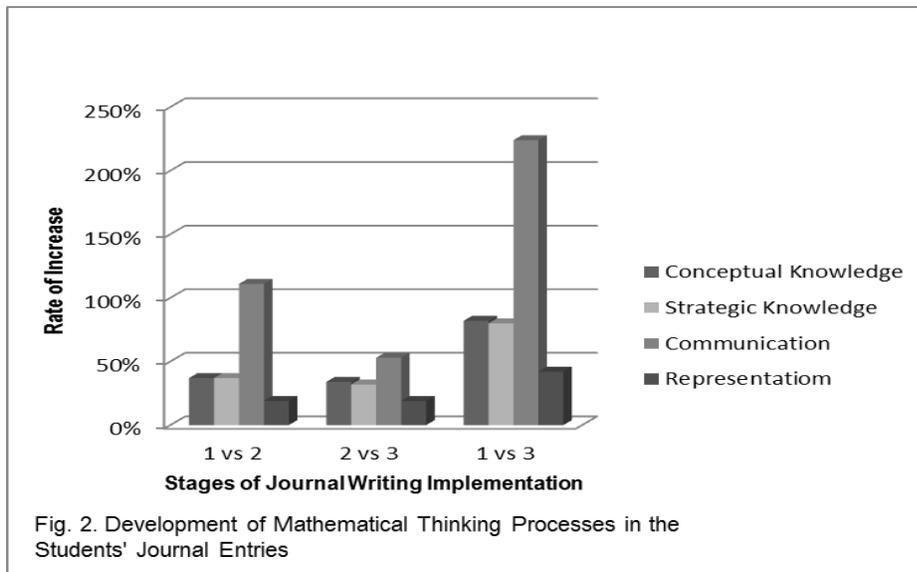
Legend: L – low, MH – Moderately High, H – high, VH – Very High

**Development of the Mathematical Thinking Processes in the Students' Journal Entries**

The combined assessment results of Rater 1, Rater 2 and Rater 3 on the extent of development of each strand of the mathematical thinking processes in the students' journal entries are shown in Fig 2. As shown, among the four strands, communication manifests the highest increase rates all throughout the stages while representation takes the lowest increase rates. Generally, conceptual knowledge and strategic knowledge maintain to have moderate increase rates. The result indicates that through journal writing, students' mathematical thinking processes are developed all throughout. Evidently, the most developed strand of mathematical thinking processes is communication and the least is representation.

Further investigation of the students' journal entries representing 4 different groupings in terms of the participants' mathematical ability provides notable variation in their mathematical thinking processes in terms of conceptual knowledge, strategic knowledge, communication and representation during the early

stage of journal writing implementation. The participants who have higher mathematical ability can easily cope with what is expected to manifest in each journal entry because the skills needed to complete each entry are already built in them even during the early stage.



As noted, there is only a moderate increase of development of their mathematical thinking processes within the 3 weeks of journal writing. While Respondents with average and below average mathematical ability and who are still starting to adopt the skills needed in writing, great extent of development on their mathematical thinking skills is observed. When the journal entries of all the respondents are compared from the second stage to the final stage, all of them reach at a moderate extent of development. However, when the journal entries during first stage are matched with the final stage, a great extent of development is observed for the respondents with average and below average mathematical ability and a minimal extent only for respondents with higher mathematical ability. Analyzing further the disparity in terms of the extent of development of the mathematical thinking processes of 4 different groupings for three different stages, the result indicates that upon reaching the final stage, regardless of mathematical ability, all of the respondents have achieved high level of mathematical thinking abilities.

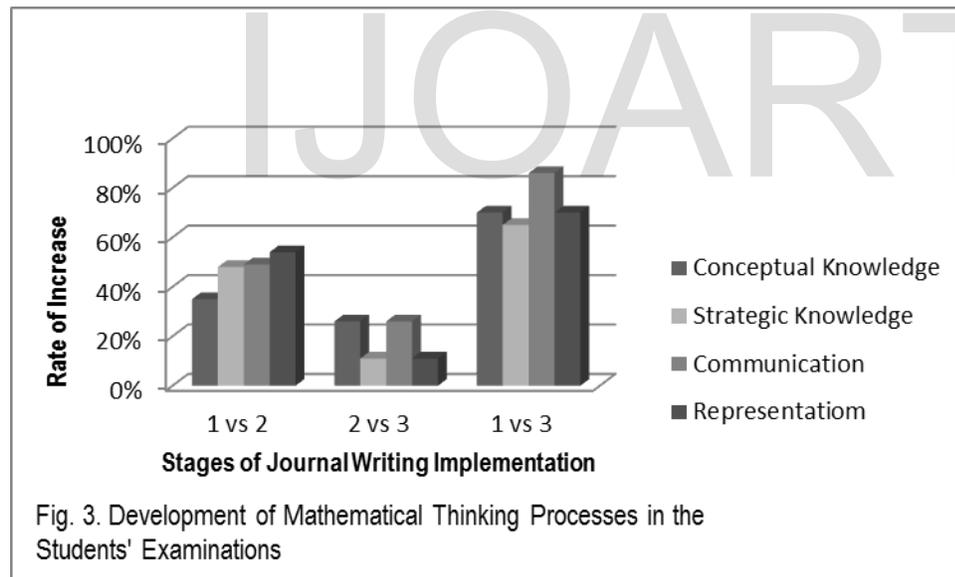
The result implies that journal writing could be one of the best strategies especially for average and low-achieving students in mathematics class. Though at first, they may struggle on the writing activities but later they may be used to it and may find journal writing to be very useful in developing mathematical thinking skills. The study of Lagan (2000) supports the present finding. According to him it can definitely not be expected that the first pieces of journal writing by an average student are lucid and logical; however, in the long run, with the teacher's facilitation, journal writing can eventually lead to disciplined thinking and increase accuracy. In the present study, accuracy is developed from the incorrect usage of grammar and then later, correct usage is already observed. Feedbacking is very helpful not only to the computational work, strategies and explanation of the process of solving but also to the corrections on grammar usage. This has been by the raters during the initial stage. Students received their papers back with some notations on the areas needed to be improved.

Also, the finding concurred with the finding of Peyton and Staton (1991), who said that journal writing can help demystify the writing process. This means that through writing periodically in their journals,

students become engaged in the process slowly, which may motivate them to write longer and more developed journal entries. Besides, journal writing supports mathematics reasoning and problem solving and helps students internalize the characteristics of effective communication (Urquhart, 2009). Students become engaged in the process slowly, which may motivate them to write longer and more developed journal entries. Besides, journal writing supports mathematics reasoning and problem solving and helps students internalize the characteristics of effective communication (Urquhart, 2009).

**Development of the Mathematical Thinking Processes in the Students' Examinations**

Shown in Fig. 3 are the combined assessments results of the 3 raters on the extent of development of each strand of the mathematical thinking processes in the students' examinations. When the assessment results of students' journals reflected in the two examinations were compared (1 vs 2), students' conceptual knowledge is less developed and the rest of the strands are fairly developed during this stage. During the middle stage (2 vs 3), students' conceptual knowledge and communication are less developed and least developed on strategic knowledge and representation between 2<sup>nd</sup> examination and 3<sup>rd</sup> examination stage. Huge rates of increase are noted between 1<sup>st</sup> examination and 3<sup>rd</sup> examination stage. Communication has as very great extent of development and a great extent for the other three strands. This means that during the final stage (1 vs 3), students' communication is very much developed and much developed for conceptual knowledge, strategic knowledge and representation. The result indicates that the integration of journal writing in students' examinations contribute to the development of their mathematical thinking processes.



**Development of the Mathematical Thinking Processes in the Students' Perceptions**

Fig. 4 displays the result of the extent of development of each strand of the mathematical thinking processes in the students' perceptions concerning the use of journal writing in class. It can be recalled that students' perceptions were identified through series of survey administered to them using a validated researcher-made questionnaire. When their perceptions were compared between successive periods with an interval of two weeks, result shows that during the initial stage (1 vs 2), the extent of development of the students' mathematical thinking processes is very minimal in all the strands. This indicates that the extent of development of the students' mathematical thinking processes concerning the use of journal writing in class as perceived by them is least developed during this stage.

During the next two weeks interval the students were asked again regarding their perceptions. As noted, middle stage (2 vs 3) and final stage (1 vs 3) manifest a little increase in terms of the extent of development of the mathematical thinking processes. During the middle stage, only representation has an extent of development which is minimal, the rest remains to have a very minimal. However during the final stage (1 vs 3), conceptual knowledge and communication go the same with the representation on a minimal extent while strategic knowledge is still on a very minimal extent. The result indicates that the students' mathematical thinking processes as perceived by them is less developed in terms of conceptual knowledge, communication and representation while least developed in terms of strategic knowledge during the final stage. The extent of development of the students' mathematical thinking processes is only minimal due to the fact that after being exposed to journal writing in just two weeks, they already perceived that journal writing has developed their thinking processes greatly.

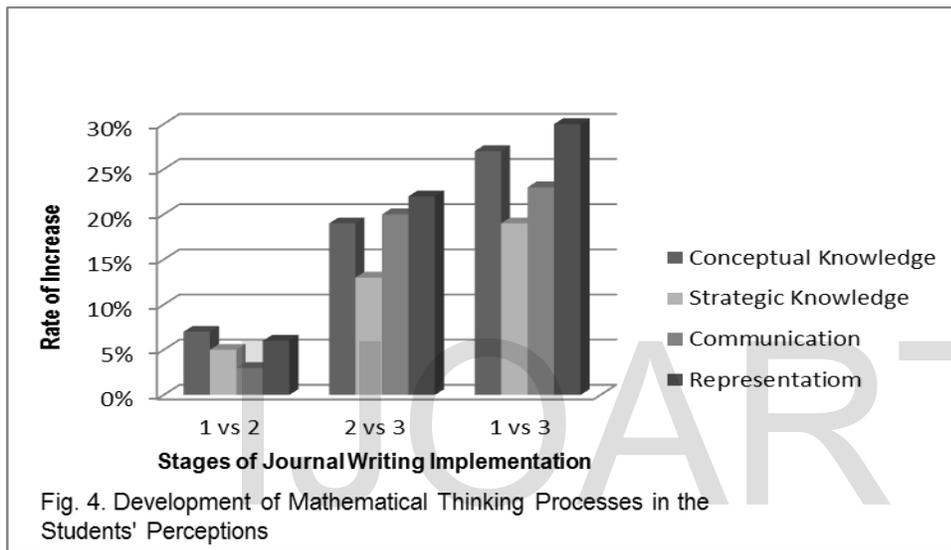


Fig. 4. Development of Mathematical Thinking Processes in the Students' Perceptions

***Benefits and Limitations encountered by Students and Teacher while integrating Journal Writing in Analytic Geometry class***

Qualitative information gleaned from final writing assignment, focus group discussion, electronic mails and exit interview with the facilitator yielded a number of distinct themes in answer to the last research question: *What are the benefits and limitations encountered by students and teacher while integrating journal writing in Analytic Geometry class?* The answers to this question are presented in tabular form and discussed into two segments, namely: on the participants' perspectives followed by the facilitator's perspectives.

***On the Participants' Perspectives***

When the participants were asked relative to the integration of journal writing in class, their answers revealed that journaling has benefited students, teacher and the mathematics department as a whole. However, some deficiencies were also noted. From the participants' responses, common themes emerged. Please refer to the table below.

**Table 3. Benefits and Limitations encountered by Students while integrating Journal Writing in Analytic Geometry class**

Common themes (Benefits)	Number of responses
<b><i>A Shift from passive to active learner</i></b> (Improved cognitive ability and active participation in class)	7
<b><i>Development of mathematical thinking processes</i></b>	
Progress in Conceptual knowledge	6
Progress in Strategic knowledge	8
Progress in Communication	8
Progress in Representation	4
<b><i>Upholding better informed future teaching</i></b> (Writing as a tool in teaching mathematics)	13
<b><i>A call for curriculum modification</i></b> (Integrating writing in other classes)	8
Common themes (Limitations)	Number of responses
<b><i>Time restriction</i></b> (Limited time is allotted in writing)	5
<b><i>Having trouble with correct use of terminologies</i></b> (Difficulty in the use of mathematical concepts)	3
<b><i>Problem Complexity</i></b> (Difficulty analyzing and answering the given problems)	5

Having the students write about mathematics not only addresses the four strands of the students' mathematical thinking processes but also have the potential to reinforce each strand in the areas of number and operation, and problem solving. The integration of journal writing in Analytic Geometry class has confirmed that requiring students to write helps them improve their cognitive skills (Kostos and Shin, 2010) and gives instructor a valuable insight into the nature of their understanding (Urquhart, 2009). Although at an early stage, some students wrote only a few which showed moderate understanding of the problem's mathematical concepts and principles with grammatical and computational errors, but in the long run, they were able to show improvement of the mathematical thinking processes. Their mathematical ability which was determined prior to the writing sessions did not generally hamper this development as manifested in the different journal writing exhibits. Regardless of their mathematical ability, quantitative and qualitative analyses showed that the more chances be given to the students to do the writing, the better development of the mathematical thinking processes is demonstrated.

Finally, the positive effect of journal writing as evidenced by the active participation of students in class and progress in mathematical thinking processes has helped sustain students' engagement in the learning process. The use of journal writing prompts activities allowed the students to express their feelings and knowledge in their own language (Adair & Houston 2001) which helped them self-confidence in dealing with their concerns.

Although, there are limitations encountered, however, these could be addressed by introducing more simplified journal prompts and also decreasing the number of journals to be accomplished. Students' voice in paper, in turn, makes journal writing an excellent means of involving students in their own education, thus making them independent learners and thinkers.

### On the Facilitator's Perspectives

During an exit dialogue with the facilitator, some themes were captured. As reflected in Table 4, one of the benefits treasured by the facilitator when journal writing was integrated in her class is it provides a greater sense of direction in her teaching. By mentioning that the class is manageable simply means that the students trusted the facilitator. This is helpful because the more the students trust the teacher, the more likely they are comfortable about revealing deeper insights into their learning (Moon, 1999). It follows that the implementation of journal writing in class was effective because of the active participation of the students. Since proper guidance on what to teach through the use of journal prompts is provided, the teacher was successful in conveying to the students all expectations with regard to completing and grading the journals. Every effort was made in ensuring that the journal writing is seen as nonthreatening and satisfying.

**Table 4. Benefits and Limitations encountered by Teacher while integrating Journal Writing in Analytic Geometry class**

<b>Emerging Themes (Benefits)</b>	
<i>Has Greater Sense of Direction</i>	<ul style="list-style-type: none"> <li>• Having manageable class</li> <li>• Proper guidance on what to teach through the use of journal prompts</li> <li>• Enthusiastic to teach since students showed active participation in class</li> </ul>
<i>Providing Insights for Instructional Starting Point</i>	<ul style="list-style-type: none"> <li>• Encourages students' self-evaluation – giving hint to teacher either to re-teach the lesson or proceed to the next topic</li> <li>• Diagnosing students' weaknesses</li> </ul>
<b>Emerging Theme (Limitations)</b>	
<i>Time Impediment</i>	<ul style="list-style-type: none"> <li>• Difficulty in allocating time for students' journals</li> <li>• Suggested to lessen the number of journals, one prompt per week</li> </ul>

Also, the teacher emphasized in her responses to an interview that journal writing strengthened formative assessment. She regarded journal writing as beneficial not only for the students but for her as a facilitator. In this study, the teacher was not given additional work to accomplish like checking of students' journal entries and giving feedback. The researcher and the two other raters held responsible for the giving of feedback to students' journal entries. However, she happened to read them and diagnosed students' strengths and weaknesses hence, she was able to adjust her teaching. Written explanations of a student's problem solving process has allowed the teacher to understand and assess the student's thinking and comprehension of material in a way that computational steps alone may not provide (Drake and Amspaugh, 1994). The depth of a student's misunderstanding was determined and thus provides insight for an instructional starting point. In addition, the information the teacher got from reading students' entries has helped her understand that mathematics is more than a rote computation.

One of the downsides of implementing journal writing in class as experienced by the teacher-facilitator was difficulty in allocating time for journaling. This is also the most noticeable problem encountered by many researchers. According to Quinn & Wilson (1997), factor such as time is considered

impediments to the use of writing in the teaching of mathematics. Nevertheless, the teacher facilitated it by giving extra time for her students to accomplish the writing tasks assigned to them. As what Waywood (1992) advised to teachers who are interested in using journals, teachers must allow class and homework time for journal writing, so that it is valued by the students as a means of assessment. This advice was apparent the way the facilitator coped time constraint.

## CONCLUSION

The following conclusions are drawn based on the findings of this investigation.

1. The profile of the participants in terms of their mathematical ability is average.
2. The level of mathematical thinking processes in the students' journal entries changes over time generally from moderately high level to a high level.
3. The extent of development of the mathematical thinking processes in the students' journal entries is not similar from one set to another. Evidently, the most developed strand of mathematical thinking processes is communication and the least is representation. Generally, conceptual knowledge and strategic knowledge maintained to be at a moderate extent.
4. Further analysis of the students' journal entries disclosed that regardless of the students' mathematical ability during the initial stage of journal writing implementation, all of them manifest high level of mathematical thinking processes upon reaching the final stage.
5. The extent of development of the mathematical thinking processes in the students' examinations is not similar from one set to another. Among the strands of mathematical thinking processes, communication has a very great extent of development and a great extent for the other three strands.
6. The extent of development of the mathematical thinking processes in the students' perceptions is minimal.
7. Students' exposure to journal writing in class has benefited them though some deficiencies are noted. There are four identified benefits emerged. These are a shift from passive to active learner; the development of mathematical thinking skills; upholding better informed future teaching, and a call for curriculum modification. Limitations encountered were time restriction, having trouble with the correct use of terminologies, and problem complexity.
8. Students' exposure to journal writing in class has benefited the teacher in the sense that journal writing has provided her with a greater sense of direction in her teaching and provided her with an instructional starting point though she grappled with allocating enough time for integrating journal writing in class.

## RECOMMENDATION

On the bases of the aforementioned findings of the study and drawn conclusions, the following are recommended:

1. Given that journal writing has contributed an improvement on the level of students' mathematical thinking processes in some degree, teachers are encouraged to continuously provide students with worthwhile problem-solving tasks which allow them to explain their thoughts in-depth and go beyond the traditional basic steps to arrive at a solution.
2. Since this study has provided evidence that the longer time the students were exposed to writing the more their mathematical thinking processes are developed, journal writing experience can be enhanced through giving of homework focusing on writing tasks that may reveal attitudes, anxieties and beliefs about mathematics that might be interfering with the students' learning.

3. As journal writing transformed students from being passive to active learners, this new mode of teaching may call for curriculum modification. The use of journal writing should be emphasized in mathematics curriculum and possibly be reflected in the syllabus so that other teachers will have also chance to subscribe to this kind of strategy. Students' active participation in the learning process may also promote active knowledge construction which facilitates the development of meaningful and deeper understanding.

4. It is always necessary to provide students with feedback on their journal entries to keep them going. Feedbacks given to students will provide important issues students can address, thus will motivate them to write more and more and be more accurate in grammar usage.

5. In order to address concern regarding time constraint, teachers must lessen the number of prompts focusing on cognitive domains. A good number is one journal entry per week (to be accomplished during class hour) so students will not become overworked, and the teachers will be able to keep up with the grading. Teachers may do negotiation with students on the frequency of journals to be accomplished per week and how often they should turn.

6. Teachers should not underestimate low-achieving students in their capacity to write because this study has provided evidence that regardless of students' mathematical ability, in a long run, mathematical thinking processes will be developed.

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