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HIGH SCHOOL SENIORS WITH ALTER NATIVE CONCEPTIONS ON EXPONENTS AND LOGARITHMS

by

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TEACHING WITH – ERROR HIGH APTITUDE MATHEMATICALLY – CHALLENGED HIGH SCHOOL SENIORS WITH ALTER NATIVE CONCEPTIONS ON EXPONENTS AND LOGARITHMS

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ABSTRACT

This action research aimed to determine the mastery level, the common alternative conceptions and the reduction rates of alternative conceptions on exponents and logarithms using Teaching with – Error Analysis (TWEA) as strategic instruction to High Aptitude Mathematically- Challenged (HAMC) high school seniors. It used qualitative and quantitative approach and action research type. TWEA framework utilized the Test for Understanding Exponents and Logarithms (TUEL) and researcher-designed worksheets and activities. HAMC students have difficulty recalling directly and applying the definition, properties, rules and laws of exponents and logarithms. They are incapable of solving exponential and logarithmic equations which require higher cognitive level of thinking due to insufficient knowledge of combining properties, rules and laws to work with exponents and logarithms. TWEA increased students' level of mastery and reduced students' alternative conceptions about exponents and logarithms. The use of mathematical teaching framework like TWEA helps teachers realize students' understanding of mathematics concepts.

INTRODUCTION

Students have many conceptions in learning Mathematics which hinder them to progress and study the subject. Kesan and Kaya (2007) stated that the reason for that matter is that students have difficulties in understanding scientific concepts. Learning concepts in a non-meaningful way leads to the formation and increasing of the misconceptions. Misconceptions are big impediment in meaningful learning. Especially, the permanent mistakes create great difficulties for the Mathematics education in reaching its goals if they are not avoided on time.

Many studies have shown that misconceptions are permanent and continuous, and at the same time they are not sufficient to make the student develop the right concepts. However, according to Swan (2001), frequently, a "misconception" is not wrong thinking but is a concept in embryo or a local generalization that student has made. It may in fact be a natural stage of development.

Kelley (1997) shed light on the vital role of identifying alternative conceptions in the teaching-learning process. Conceptions can become a factor that impedes learners to understand scientific principles and concepts. As a remedy, proper choice of teaching strategies should be taken into account to prevent students' consistent beliefs of concepts.

As stated by Glynn (2007), the use of analogy as a teaching strategy can aid in prevention of alternative conceptions since it facilitates students in building bridges between old to new knowledge. Analogy provides the relevance and motivation to learners thus making them engage learning. Analogy opens the learner's mind to modify existing knowledge and gain real and true learning.

This study supports the theory of conceptual change which has already been applied to a considerable number of cases to science learning and some recent studies investigated conceptual change in the learning process of mathematical concepts. These are referred to the concepts of numbers (Merenluoto and Lehtinen, 2002) to the transition from one set of numbers to a more extensive one (Vosniadou, 2004) and to infinity (Ladhani, 2002).

In this study, the researcher examined the learning development of students' alternative conceptions on common exponentials and logarithms. This way of conceptualizing skills in exponents and logarithms provided a useful framework for thinking about how students could think about these concepts since it provides details of how they operate on the rules, properties and laws of exponents and logarithms.

In the study of Ayop, Hoop and Singh (2005) showed that most Malaysian students liked to skip certain important steps when working with logarithms. Moreover, among the laws of the logarithms, the first and second laws emerged to rank second and third respectively, with the most frequent number of mistakes committed by the student-respondents. In their study of logarithms, students mixed up exponential and logarithmic rules. In particular, students often write $\log x - \log y = \frac{\log x}{\log y}$ instead of the correct expression $\log \frac{x}{y}$. Students also linearize rules and produce such as *log (a+b) = log a + log b* or log (2x) = *2log x*. Ayop et al. (2005) elaborated that when students are solving logarithmic equation, students forget to check if the answer is in the domain. If students got two answers and the first one checks, they tend to automatically eliminate the second choice. Students often do not check this. This demonstrates the misconception. Chua (2003) posited that if teachers are aware of common errors or misconceptions and their possible causes, they can actually use them as opportunities for learning rather than see them as inevitable problems. Since, teachers can engage students in a discussion of the answer to incorrect solutions of exponentials or logarithmic problems. In the same study, errors can be used as "springboard for inquiry' to address misconceptions during teaching. Berezovski (2004) suggested that teachers should implement proper techniques in teaching exponentials and logarithms so that students can acquire deep understanding of these topics.

Errors have to be corrected methodologically by making students aware of their errors and by creating such situations in which students can discover their errors themselves. If in case questions are not helpful, then the next action teachers should take is to create contradictions, contrasts or to give a counterexample and if students do not correct their errors themselves, teachers can use the help of other students. An error analysis and correction with the participation of good students can be educational for others, also for good students (Fleming, 2013), and sometimes it is possible (or even necessary) to postpone the error discussion for the next class. It is important that students correct their errors themselves. Errors cannot play their role when they are quickly corrected by teachers or other students.

Chua (2003) posited that errors can be used as "springboard for inquiry' to address misconceptions in teaching-learning process. Teachers can involve students in activities organized around the explicit study of some previously selected errors or impromptu errors made by the students during the lessons. As suggested by the researcher, a worksheet containing both correct and incorrect solutions to some questions on exponentials and logarithms can be given to students to directly engage them to error analysis and at the same time to encourage them to pursue open-ended explorations and reflections.

Anecdotal evidences from both students and teachers over the years have consistently shown that topics on exponentials and logarithms are among the most abstract units to learn, and teach as well, in secondary schools. Chua (2003) confirmed that even though students can often perform the tasks that are given in the text and during the examinations, their understanding of the fundamental concepts of these functions still remains in doubt. Chua (2003) recommended that errors should be used as springboard for cognitive conflict to provoke students' thinking and to guide them correctly with their alternative conceptions or misconceptions. For this strategy to work effectively as conceptual change model, it is important to provide students with immediate feedback so that errors and misconceptions are challenged as soon as they occur. Similarly, it is important to engage students in an interactive discussion to talk about their work and perhaps to justify their answers as well. *Teaching with – Error Analysis* needs a worksheet containing both correct and incorrect solutions to some questions and can be given to students to directly engage them in the error analysis and, at the same time, to encourage them to pursue open-ended explorations and reflections.

The aforecited literatures and studies provided direction to the researcher to make its conceptual paradigm to conduct this study. The review on the clusters of misconceptions provided by Ayop et al. (2005), Allen (2006) and Cohen (2000) provided an interest to the researcher to use as alternative conceptions' nomenclature on its identification from the high aptitude mathematically-challenged senior students of Nueva Vizcaya General Comprehensive High School.

The study aimed to determine the level of mastery and alternative conceptions of high aptitude mathematically – challenged senior students of Nueva Vizcaya General Comprehensive High School (NVGCHS) in solving exponential and logarithmic equations and expressions and to find the reduction rates of students' alternative conceptions on exponents and logarithms using *Teaching with - Error Analysis* (TWEA).

Hence, the following were the compelling objectives of the study: 1) to determine the level of mastery of the high aptitude mathematically – challenged senior students on exponents and logarithms before and after the implementation of the *Teaching with – Error Analysis*; 2) to identify the common alternative conceptions of the high aptitude mathematically-challenged senior students about exponents and logarithms; 3) to find reduction rate of students' alternative conceptions about exponents and logarithms after the implementation of the *Teaching with – Error Analysis*; and, 4) to determine if the reduction of students' alternative conceptions about exponents and logarithms significant.

METHODOLOGY AND RESEARCH DESIGN

The study employed the descriptive (quantitative) and qualitative type of research methods. It employed also an action research type which is a form of investigation designed for use by teachers which, according to Parsons and Brown (2002), is an attempt to solve problems and improve professional practices in classrooms. Thus, this type of research was used to determine the extent of effect of *Teaching with – Error Analysis* to high aptitude mathematically – challenged seniors in increasing level of mastery and reducing alternative conceptions on exponents and logarithms.

The respondents were chosen through a non – probability purposive sampling. A purposive sample, also commonly called a judgmental sample, is one that is selected based on the knowledge of a population and the purpose of the study. The subjects are selected because of some characteristics (Reyes, 2003). High school seniors enrolled on the Engineering Science Education Program were classified as high aptitude students and were further classified based on their first departmental scores with topics on exponents and logarithms. Those with scores below 74% were categorized as mathematically-challenged students. 28 students from the two sections of the ESEP program were identified as respondents for the study.

The gathering tools utilized in the study are the Test for Understanding Exponents and Logarithms (TUEL), and a researcher-made TWEA worksheets which were pre-administered to selected fourth year students under the Basic Education Curriculum which yielded an internal consistency of 0.82 (*Cronbach's Alpha*) which is a good classroom assessment tool.

A detailed item-by-item analysis was carried out by examining students' responses for each test item using two categories; correct and incorrect answers. To determine students' level of mastery on exponents and logarithms, one point corresponds to each correct answer while zero for incorrect ones. The number of students who got correct answer was transformed into percent and was described according to the slightly modified scales provided by Sheridan (2014) as no mastery (0 – 0.99), very low mastery (10 – 29.99), low mastery (30 – 49.99), average mastery (50 – 69.99), moving towards mastery (70 – 89.99) and with mastery (90 and above). Reduction rates were computed using the *Conceptual Diagnostic Test* formula given by Zeilik (2005). This was obtained by subtracting frequency score on the post-test from the frequency score on the pre-test divided by the frequency score on the pre-test or $\frac{pretest - posttest}{pretest}$. Percent scores were categorized as low (below 39%), good/reasonable (40 –70%) and high (71-100%). To determine if the reduction of the students' alternative conceptions on exponents and logarithms is significant, *McNemar* Change Test was used and was set at 5% level of significance. Significant reduction was categorized into positive and negative. Significant positive reduction occurs when alternative conceptions were reduced while significant negativereduction occurs when alternative conceptions were increased after the implementation of TWEA.

RESULTS AND DISCUSSIONS

1. Mastery Level on Exponents and Logarithms

High aptitude mathematically – challenged (HAMC) high school seniors have low mastery of exponents and logarithms (see Table 1). Particularly, the mean percent score along the *Knowledge* category is about 38% described as low mastery, and, predictably when items became more difficult, the mean percent score dipped to a level of about 30% along *Understanding/Comprehension* category and to a very low of about 17% along *Application* category. These findings suggest that most HAMC students were unsuccessful with routine and familiar items, and, they did not perform as well when the items deviated slightly from the familiar items to those that involve applications of the laws, rules of exponents and logarithms. These results are consistent with Chua (2003) and Ayop et al.'s (2005) findings on the lack of good understanding of exponents and logarithms among students and are less capable to solve problems which require higher level of cognitive thinking.

Knowledge cognitive level of students has increased by 30% from 38% to an average mastery of about 68%, while, an increase of 29% from low mastery of 30% to an average mastery of about 59% along *Comprehension* level. An increase of about 34% from a very low mastery to nearing mastery of about 67% along *Application* level has incurred. In general, there is a considerable increase in the level of mastery of exponents and logarithms from 31% to an average mastery of 67%.

This indicates that *Teaching with – Error Analysis* helped the HAMC senior students increase their level of mastery on exponents and logarithms. These findings validate and reflect increase level of mastery of exponents and logarithms as advanced in the assessment results of

TWEA activities 3 and 6 with respective mean scores of about 89% and 79%.

2. Alternative Conceptions on Exponents and Logarithms

None of the HAMC students obtained full marked in the TUEL. The indication of insufficient skills in solving exponents and logarithms indicates that students faced difficulties when working with exponents and logarithms. These results reflect agreement with Chua (2003) and Berezovski (2004) on students' alternative conceptions while solving exponents and logarithmic problems. They strongly concurred that students need some help in learning and expanding their knowledge on these topics. These findings also validate the category made for high aptitude seniors as mathematically-challenged students.

A serious alternative conception of students made in TUEL is the linearization of logarithmic rules (C9) which surfaced the highest frequency of 28 (refer to Table 2). This is consistent with Allen's (2006) finding that most often students write $\log(a+b)$ as $\log a + \log b$ or $\log(2x) = 2\log x$ which are also observed from the HAMC students.

These are followed by incorrect change of logarithm to index form and vice versa (C7) and having incorrect conception about the logarithm of a quotient (C14) which surfaced both frequencies of 27. Other than that, among the three laws of logarithm, most of the students (frequency = 27) made mistake when working with the logarithm of a quotient (C14). This is consistent with Ayop et al.'s (2005) findings that the product and quotient rules emerged to be the most common mistakes committed by students. Coherent with most frequent observed alternative conceptions found in the results of TWEA activities 1 and 4 (see appendix J), which are misconception on the logarithm of a quotient and misconception about the power rule for exponents.

Some (frequency = 23) of the HAMC students did mistakes in using the inverse property of logarithm (C12). Another serious alternative conceptions of students made in TUEL are the linearized rules and laws of exponents (C1) and misused of the negative exponents (C5) with respective frequencies of 26 and 18. These adhere with Cohen as cited by Campo (2010) that most students have misconception on negative exponents and often linearized rules and laws on exponents.

An illustrative example of an alternative conception on indices (C7) *Figure 1 which specifically presents the alternative conception of Diana when transforming logarithmic expression to exponential form. First she equated (x + 1) with -2 as shown in the erasures of her solution. She did not know the base of $\log(x+1)$ to be 10 and instead she used -2 which is on the right-hand side of the logarithmic equation. Consequently, the answer yielded was wrong due to incorrect change of logarithm to index form (C7).

On the other hand, **Figure 2 shows Benedict's solution to Item 7 where it asked to express $2\log_5 3 + 2\log_5 5$ in a single logarithm. His first two steps were correct using the logarithm of a product. Surprisingly, step 3 which is the final answer of Benedict shows linearization of a rule of logarithm where 9 and 25 seemed to be added in step 2 to arrive at $\log_5 34$. This solution manifests an alternative conception on the linearized rules of logarithm (C9).

3. Reduction Rates of Alternative Conceptions

Among the highest observed frequency of alternative conception during the pre-test (see Table 3), misconception about the inverse law of logarithm surfaced to have the highest reduction rate of about 87%. This is followed by wrong concept of antilogarithm with a reduction rate of about 82%.

Incorrect change of logarithm to index form and vice versa (C7) and simply cancelling out logarithmic notation or treating logarithm as variable (C8) appeared to have good reduction rates of about 59% and 64% respectively. Also, linearized rules and laws on exponents (C1) and logarithms (C9) emerged to have good reduction rates of 69% and 68% respectively.

On the other hand, misconception about the power rule (C3) for exponents and misconception about the logarithm of a quotient (C14) showed reduction rates of 14% and 19% respectively qualitatively described as “low” reduction rates. These should be notably addressed since these alternative conceptions surfaced to have high frequencies in the pre-test of TUEL.

4. Significant Reduction of Alternative Conceptions

13 items on the TUEL emerged to have significant change with p-values which are lower than 0.05 (see Table 4). 12 items were found to have significant positive change implying that students’ alternative conceptions associated with these items were reduced after the implementation of the TWEA. One item (Item 14) surfaced to have significant negative change implying that the alternative conception associated with this item was increased which is misconception about the logarithm of a quotient (C14).

Among the alternative conceptions associated with the 12 items which had significant positive changes were misconceptions about the power rule, linearization about the laws and rules of exponents, misuse of the inverse property of logarithm, linearization of logarithmic laws, incorrect change of logarithm to index form and vice versa, misconception about the logarithm of a quotient, wrong concept of antilogarithm and treating logarithm as a variable or cancelling out logarithmic notation.

Whereas, 13 items surfaced to have p-values higher than 0.05, which means that students’ alternative conceptions associated with these items on the TUEL were not significantly reduced. Among the students’ alternative conceptions which were not reduced were: misuse of the definitions of negative exponents, misconception about the logarithm of the product, misuse of one-to-one property of logarithm, misconception about the quotient rule and misconception about the logarithm of a power.

CONCLUSIONS

HAMC students have difficulty recalling directly and applying the definition, properties, rules and laws of exponents and logarithms. HAMC students are incapable of solving exponential and logarithmic equations which require higher cognitive level of thinking due to insufficient knowledge of combining properties, rules and laws to work with exponents and logarithms.

After the implementation of the TWEA, students’ level of mastery on exponents and logarithms was increased. TWEA reduced students’ alternative conceptions on exponents and logarithms particularly on the inverse property of logarithm, antilogarithm, exponential laws/rules and logarithmic laws/rules and on changing logarithm to index form and vice versa.

RECOMMENDATIONS

Mathematics educators need to stress on the differences between distributive law and multiplicative law with the laws of exponents and logarithms. Also, teachers may find good approaches to ensure that students understand the differences of the laws that occur in algebraic operations. To constantly watch the understanding of students on exponents and logarithms, it is vital for teachers to have some test for seeking some information about students' level of understanding exponents and logarithms like the TUEL. Furthermore, teachers have to clearly explain instructional words in logarithmic tasks like "express", "convert", "find the value", "evaluate", "simplify", "show" and the like. Since the framework *Teaching with - Error Analysis* was found to help reduce alternative conceptions of high aptitude mathematically- challenged students about exponents and logarithms, it is highly recommended for teachers to use the same as remediation to students with difficulties on such topics.

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List of Tables/Results

Table 1: Level of Mastery of Exponents and Logarithms (Pre and Post Tests)

Pretest Cognitive Level	Mean Percent	Description	Posttest Mean Percent	Description
Knowledge	38%	Low Mastery	68%	Average Mastery
Mastery/ Comprehension	30%	Low Mastery	59%	Average Mastery
Application	17%	Very Low Mastery	74%	Moving Towards Mastery
Overall	***31%***	***Low Mastery***	***67%***	***Average Mastery***

Table 2: Alternative Conceptions on Exponents and Logarithms

Codes	Alternative Conceptions	Frequency in TUEL
C1	Linearized Rules/Laws on Exponents	26
C2	Multiplying base with exponents	13
C3	Misconception about the Power Rule	22
C4	Misconception about the Quotient Rule	3
C5	Misuse of the definition of the negative exponents	18
C6	Incorrect use of previous law of exponent to expand knowledge in other laws	6
C7	Incorrect change of logarithm to index form and vice versa	27
C8	Simply cancelling out logarithmic notation/ Treating logarithm as a variable	14
C9	Linearized logarithmic rules	28
C10	Wrong concept of antilogarithm	11
C11	Misuse of one-to-one property of logarithm	14
C12	Misuse of inverse property of logarithm	23
C13	Misconception about the Logarithm of a Product	11
C14	Misconception about the Logarithm of a Quotient	27
C15	Misconception about the Logarithm of a Power	14

Table 3: Reduction Rates of the Students' Alternative Conceptions on Exponents and Logarithms

Codes	Alternative Conceptions	Frequency in TUEL		Reduction Rates	Description
		Pretest	Posttest		
C1	Linearized Rules/Laws on Exponents	26	8	69%	Good
C2	Multiplying base with exponents	13	7	46%	Good
C3	Misconception about the Power Rule	22	19	14%	Low
C4	Misconception about the Quotient Rule	3	3	0%	Low
C5	Misuse of the definition of the negative exponents	18	13	28%	Low
C6	Incorrect use of previous law of exponent to expand knowledge in other laws	6	0	100%	High
C7	Incorrect change of logarithm to index form and vice versa	27	11	59%	Good
C8	Simply cancelling out logarithmic notation/ Treating logarithm as a variable	14	5	64%	Good
C9	Linearized logarithmic rules	28	9	68%	Good
C10	Wrong concept of antilogarithm	11	2	82%	High
C11	Misuse of one-to-one property of logarithm	14	20	-42%	Low
C12	Misuse of inverse property of logarithm	23	3	87%	
C13	Misconception about the Logarithm of a Product	11	10	9%	Low
C14	Misconception about the Logarithm of a Quotient	27	22	19%	Low
C15	Misconception about the Logarithm of a Power	14	9	36%	Low
	Overall			***42%***	***Good***

Table 4: McNemar Change Test on the Reduction of Students' Alternative Conceptions

Items on TUEL	**Common Alternative Conceptions**	**p-values**	**Description**
1. Solve for *x* in —— **.**	C2	**0.007**	**Significant +**
2. Find all *x* such that —— **.**	C5	0.092	Not significant
3. Solve for x in the equation .	C12	**0.002**	**Significant +**
4. Solve for x in the equation	C12	**0.039**	**Significant +**
5. Find a value of x such that – – **.**	C3	0.453	Not significant
6. Express **log520 – 2log510** as a single number.	C14	**0.002**	**Significant +**
7. Express **2log5 3 + 2log5 5** as a single logarithm.	C9	**0.002**	**Significant +**
8. Solve for x in the equation: — –	C5	**0.022**	**Significant +**
9. Solve for x in the equation – — **.**	C3	0.109	Not significant
10. Express as a single logarithm.	C14	**0.001**	**Significant +**
11. Write **log(x +1) = -2** in exponential form.	C7	**0.016**	**Significant +**
12. If **log 2 □ 0.301** and **log 3 □ 0.477**, what is the approximate value of **2log3 + log6**?	C9	0.210	Not significant
13. Evaluate the expression **. 3log – 3**	C7	0.103	Not significant
14. What is the value of – ?	C15	**0.035**	**Significant -**
15. Solve for x in $\mathbf{3^{x+1} + 1 = 2}$.	C1	**0.047**	**Significant +**
16. Evaluate **3log5 +2log2 -log5**.	C14	**0.049**	**Significant +**
17. Express in terms of **m** and **n** the expression **logX24** given that **log2 x = m** and **log3 x = n**.	C14	0.250	Not significant

18. Solve for x in $\mathbf{4^{x+1} + 2 = 3}$.	C1	0.388	Not significant
19. Solve for x in **$\log_6 2 + \log_6 x = 2$**.	C8	**0.039**	**Significant +**
20. Expand completely the expression	C15	0.549	Not significant
21. Find for the value of *x* in **2log(x+1) =0.**	C11	0.359	Not significant
22. For what value of *x* is $\mathbf{9^x - 3^x - 6 = 0}$?	C1	**0.047**	**Significant +**
23. Solve for the value of x in **$\log_x$ – = - 1.**	C7	0.267	Not significant
24. Evaluate .	C15	0.180	Not significant
25. Evaluate .	C14	0.344	Not significant
26. Solve for x in **$\log_5(3x+4) = \log_5(5x-6)$**.	C11	0.547	Not significant

* p –value is significant at 5 % level; + (positive) , - (negative)

Sample Figures

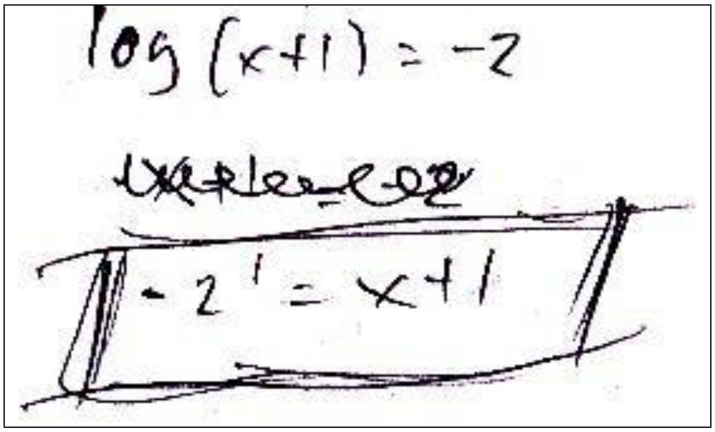

**Figure 1*. Diana’s Solution to Item 11: Write log(x +1) = -2 in exponential form.

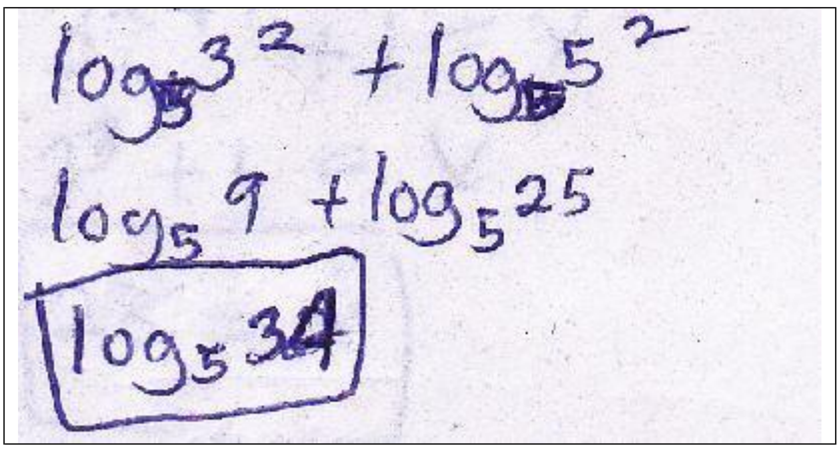

***Figure 2*. Benedict’s Solution to Item 7: Express $2\log_5 3 + 2\log_5 5$ as a single logarithm.