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Full Length Research Paper

Validation of module on exponential and logarithmic functions using the understanding by design lesson plan for grade 11 mathematics students

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ABSTRACT

The study aimed to develop and validate learning module on exponential and logarithmic functions based on the Understanding by Design lesson plan. The study was descriptive in nature, describing the instructional materials and its properties. The research flow was based on the works of Emily K. Dunsker in 2005 and the suggested procedure on formative evaluation by Talisayon and Vistro-Yu. Purposive sampling technique was used in determining the respondents. Respondents involved selected mathematics experts and grade 11 students. They were responsible for evaluating the module. Feedbacks of expert had served as guide in the module revision. Student respondents were involved in the formative evaluation. A word-sentence list forms were given to students to identify difficult or vague words, phrases and sentences as they read the module carefully. The module was subjected to readability test to determine the student involvement index, communication index and the grade level of the module. The study showed that the module has high involvement index, the communication index fell out of the acceptable range and the module level was college. These results called for another revision with complete change in structure and mode of presentation but still based on the Understanding by Design lesson plan. The study recommended to revised module and to subject it to readability test again to ensure that the module would be appropriate to the users. A summative evaluation is also recommended to determine its effectiveness.

Keywords: Validation, module, readability test.

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INTRODUCTION

The performance of Filipino students in mathematics as shown in the result of the National Achievement Test is deteriorating. According to an article online entitled “2/3 Philippine High Schools Obtained Low NAT Scores” by newsinfo.inquirer.com, almost two-thirds of the country’s high schools fared poorly in the National Achievement Test (NAT) in 2010 with some 67.10 percent of schools getting below average NAT scores. This prompted Education Secretary Armin Luistro to order school officials to exert greater effort in raising NAT scores among elementary and high school students (Quismundo, 2011).

Amidst this problem, mathematics educators seek ways and means to remedy the problem. These remedies include: mathematics curriculum evaluation and revision to ensure that the educational framework has responded to the students’ needs; adoption and implementation of new methods and techniques in teaching mathematics other than the conventional lecture-discussion method and; creation of tools to bring a different learning experience in learning math such as the use of mathematics software and learning modules.

Several researches proved that modules are effective tools in learning. The study on the use of teaching module based on radical constructivism towards rural students in Sabah showed that the use of Geography

Teaching Module CSAA can improve students' thinking skills. Furthermore, its implementation could increase thinking skills as the use of student-centered approach to encourage students to participate actively in the discovery of knowledge (Matanluk et al., 2013).

The study on the use of interactive learning modules in classroom study for computer science education revealed that most student respondents preferred the use of interactive learning modules over reading texts, working in small groups, doing written homework and video lecture (Jamwal, 2012).

Similarly, findings of the study on development and validation of instructional modules on rational expressions and variations demonstrated that the use of well-designed instructional modules can be effective in improving students' knowledge and understanding of the topics covered in rational expressions and variations. This is verified by the significant difference in the performance of students in the pre-test and post-test of the students (Torrefranca, 2017).

Jay McTighe and Grant Wiggins Understanding by Design is a framework and accompanying design process for thinking decisively about unit lesson planning (Ray, 2012). It offers a planning process and structure to guide curriculum, assessment and instruction. It is based on seven key tenets, which includes the following:
1) Learning is enhanced when teachers think purposely about curricular planning. The UbD® framework helps this process without offering a rigid process or prescriptive recipe; 2) The UbD® framework helps focus curriculum and teaching on the development and deepening of student understanding and transfer learning; 3) Understanding is revealed when students autonomously make sense of and transfer their learning through authentic performance. Six facets of understanding – the capacity to explain, interpret, apply, shift perspective, empathize, and self-assess – can serve as indicators of understanding; 4) Effective curriculum is planned backward from long-term, desired results through a three-stage design process. This process helps avoid the common problems of treating the textbook as the curriculum rather than a resource, and activity-oriented teaching in which no clear priorities and purposes are apparent; 5) Teachers are coaches of understanding, not mere purveyors of content knowledge, skill, or activity. They focus on ensuring that learning happens, not just teaching (and assuming that what was taught was learned); they always aim at and check for successful meaning making and transfer by the learner; 6) Regularly reviewing units and curriculum against standards enhances curricular quality and effectiveness, and provides engaging and professional discussions; and 7) The UbD® framework reflects a continual improvement approach to student achievement and teacher craft. The results of our designs (student performance) inform needed adjustments in curriculum as well as instruction so that student learning is maximized (McTighe and Wiggins, 2012)."

Learning the effectiveness of the learning modules and appealing tenets of the Understanding by Design, the researcher was motivated to develop a learning module on exponential and logarithmic functions for grade 11 mathematics students using the Understanding by Design lesson plan. The researcher thought that material such as this might help in increasing students' engagement in learning mathematics. Moreover, the researcher would want to subject the material to formative evaluation to make sure that the material would be appropriate and useful to the students who would use it.

Statement of the problem

The study aimed to develop and to validate module based on the Understanding By Design lesson plan. Specifically the study would aim to answer the following questions:

1. What are the feedbacks of experts on the first draft of the developed module?
2. What is the student involvement index of the module?
3. What is the communication index of the module?
4. What is grade level of the module?
5. What is the description of the revised module?

Scope and delimitation

The study is limited only to development of module and, validation of it by experts and students. The module had undergone readability test to determine the module's communication index, student involvement index and its grade level.

Significance of the study

This study will be beneficial to the following:

Students. This will be helpful to students because the module will provide different learning experience. Since the instructional material is self-contained, this will encourage independent learning. It will also encourage cooperative learning because the material provides group activities. Mastery of the topic is expected for it provides enough exercises for them to work on. Integration of non-math concepts is reinforced for subject appreciation.
Teachers. The study will provide alternative in managing and implementing classroom instruction. A different teaching experience is expected because the material encourages the teacher to exhibit his/her creativity in making the activities meaningful to students.
Future Researcher. The formative evaluation procedure

may help future researchers who would develop and validate instructional materials such as this module.

Conceptual framework

The study conducted by Emily K. Dunsker (2005) entitled "Development and Validation of a Systematically Designed Unit for Online Information Literacy and its Effect on Student Performance for Internet Search Training", which was published online, the author clearly taught the procedure used in development and validation of instructional material. The procedure includes the following steps : scanning text from the course workbook; collaborating with course instructors on development and validation of assessment instruments; choosing an instructional strategy; developing and selecting instructional materials; conducting a formative evaluation; revising materials and; and conducting a summative evaluation.

The manual entitled Seminar in Curriculum Design and Instruction for Science Education (Talisayon and Vistro-Yu, 1997), emphasized that curriculum materials should undergo formative evaluation. Formative evaluation involves the participation of experts and selected students. The role of the experts is to evaluate the content and structure of the curriculum material. The suggestions of these experts are essential in the improvement of the curriculum material. Once, the suggestions are considered for the improvement of the material, the curriculum material is subjected to readability test. Readability tests are formulae for evaluating the readability of texts, usually by counting syllables, words, sentences and graphs and figures. This is very crucial because it sees to it that the material is appropriate for users. In performing the readability test, the participation of the students is very much needed. The role of the students is to read the curriculum material seriously. Thus, it is necessary for the student-participants to be responsible, patient, readers, and critical thinkers. These students will list down words, sentences, graphs and figures, which they find difficult to understand and later be used in the readability test.

The procedure used by Dunsker (2005) and the formative evaluation suggested by Talisayon and Vistro-Uy were considered in this study. Integrating the two procedures, the researcher came up with the procedure for module development shown in Figure 1.

Figure 1 shows the module development procedure. The procedure would commence by scanning textbooks in Math for Grade 11 students. The purpose of this was to find out the varying concepts and skills, which the students should learn and develop. The second step would be choosing the instructional strategy. In this study, the Understanding by Design was considered as the instructional strategy. Third step would be the preparation of the lesson plan, which would serve as guide in developing the module. Fourth would be the development of the module. At this stage, the researcher would decide on what module format and structure to use and what contents and activities to include in the instructional material. The writing of the instructional material would be part of the stage too. Fifth would be the conduct of formative evaluation. At this stage, the participation of experts and students was necessary. After the development stage, the module would be presented to mathematics experts for content evaluation. The comments and suggestions of these experts would be considered in doing the first revision. Once the revisions were made the material would be returned to the experts for review. The purpose of the review was for the experts to find out if their suggestions were incorporated in the revised material and to know if the material was ready for student evaluation. Once approved by the experts, the instructional material would be handed to selected students to read the material and to instruct them to jot down words, phrases, sentences and figures, which they consider vague or difficult to understand. The results would be utilized in readability test. Sixth would be the revising of the instructional material. At this stage, the result of the readability test is highly considered in making the final revision.

The conceptual framework of this study focused on the formative evaluation of the students. Figure 2 shows how the formative evaluation of the student was done.

The study made use of the IPO or the Input-Process-Output paradigm. The input was composed of the approved developed module and the accomplished word, sentence and figure list form. These two materials were disseminated to students. They were requested to read the module carefully and as they read they were asked to write down words, sentences and figures, which they considered difficult to understand in the word, sentence and figure list form. The accomplished word, sentence and figure list form were subjected to readability test, which was the considered as process in this study. The words and sentences that appeared in the list were used in obtaining the three important components of the readability test: the computation of the student involvement index of the module, the communication index of the module and the determination of the grade level of the module. These three components would completely describe the module. The computation results would also serve as basis for the final revision of the module.

Research design

The study made use of descriptive research design. Descriptive research aims to accurately and systematically describe a population, situation or phenomenon. The descriptive research design can use different quantitative and qualitative methods in

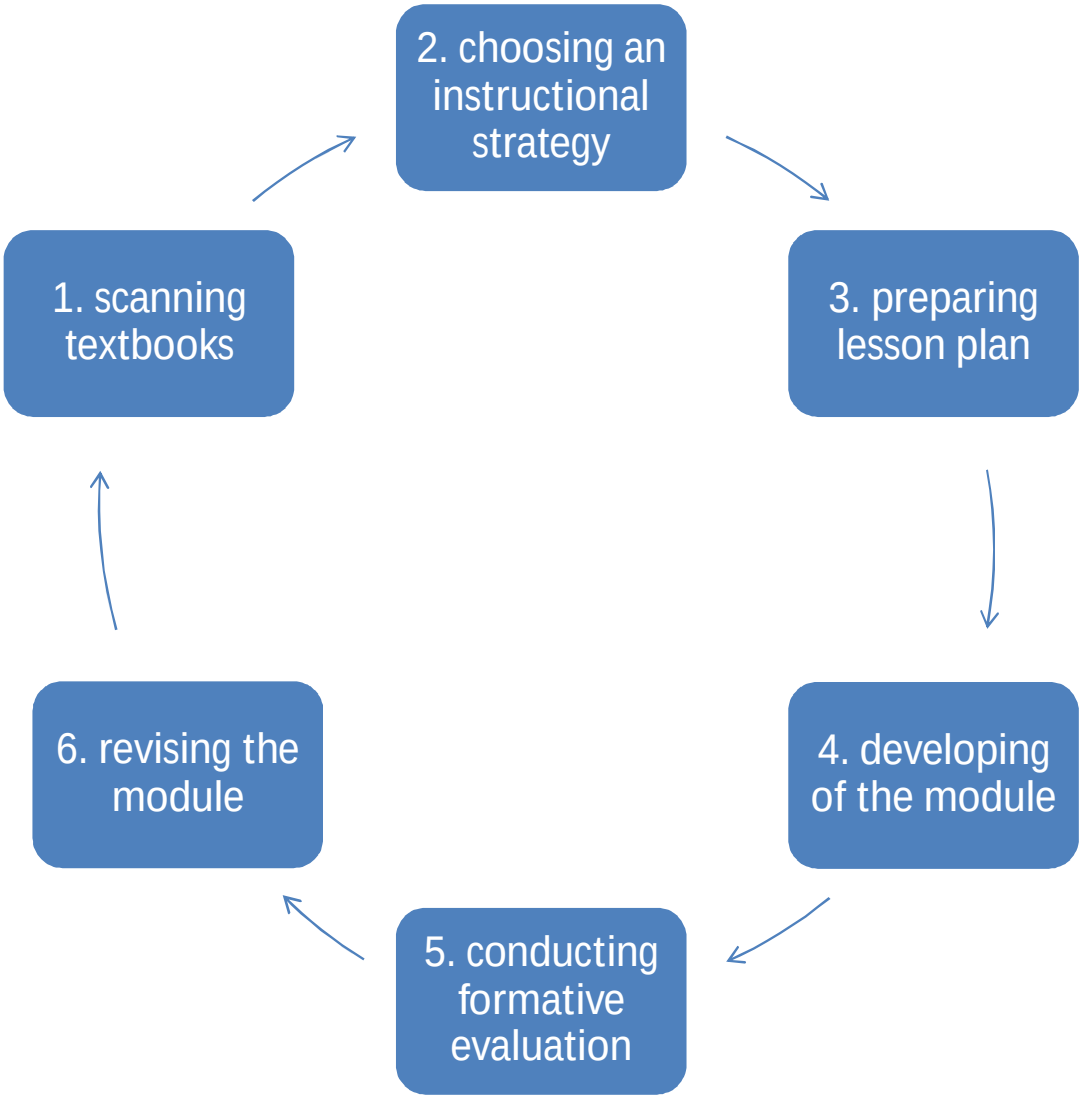

Figure 1. Module development procedure.

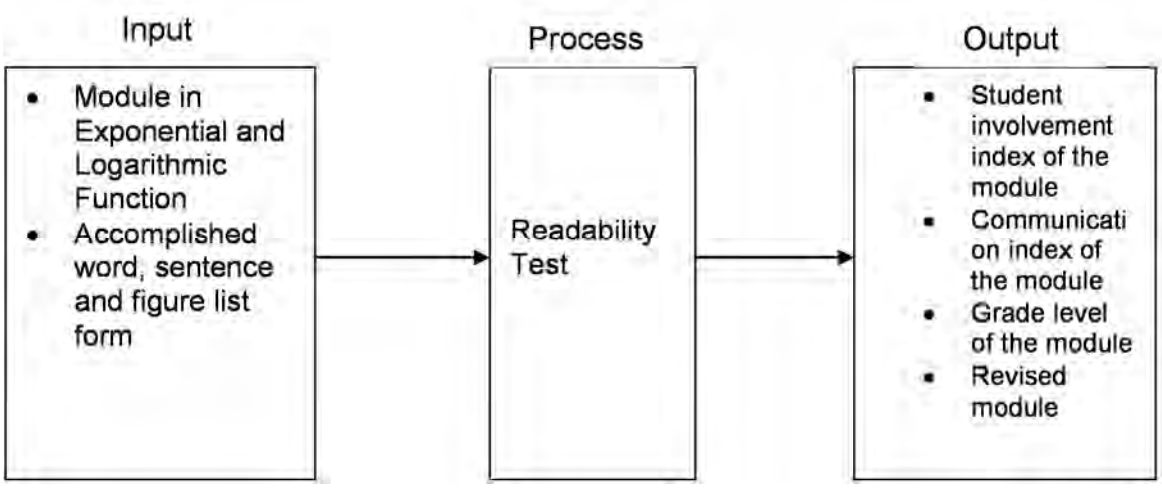

Figure 2. Research paradigm.

investigating a variable or several variables under consideration (Mccombes, 2019). This design was quite appropriate for this study because the study described the developed module and its properties.

Samples and sampling techniques

Respondents of the study were selected using the purposive sampling techniques. This was used because the study required experts, who evaluated the modules and, selected five high school students, who read, and listed down vague words, phrases and sentences, which were difficult to understand. Three experts were asked to evaluate the modules. One was a mathematics professor at Pamantsan Ng Lungsod Ng Maynila, the other was a mathematics teacher in St. Augustine College in Tanzania and the last one is a mathematics teacher in high school at St. Augustine School Tanza, Cavite. Only five students were chosen to ensure that they would seriously read the materials. With the assistance of one class adviser in fourth year high school at St. Augustine School Tanza, Cavite, who also teaches mathematics, she had chosen students who were responsible when given task to perform and the ones who had passion for reading. She chose two students, who had above average performance in math, another two, who were average performers in math and one who really dislikes math.

Research instrument

Word, sentence and figure list form was the research instrument for this study. This form allowed the respondents to list down vague and difficult words and sentences that they would encounter while reading the module.

Data gathering procedure

The data gathering procedure had begun once the module was completed. The module was given to the experts. They evaluated the material. They had to look into the format, structure, content, organization and presentation. The experts' feedbacks were considered in the revision of the material before it was handed to student respondents. Once the revisions were made, the module was shown to the experts again to gain their approval in subjecting the material to readability test. Upon their approval, copies of the module were distributed to students. They read the module and while reading them carefully with the monitoring of the class adviser, they jotted down the words, and sentences, which they considered vague and difficult to understand. When done, the class adviser retrieved the copy of the modules and the accomplished form, and gave those to the researcher. Finally, the researcher did the readability test to determine the student involvement index, communication index and the grade level of the module.

Statistical treatment

The module was subjected to readability test. The readability test involves computational formulae to determine the module's communication index, student involvement and grade level.

Student Involvement Index is the ratio of the total number of sentences in Category 2 to the total number of sentences in Category 1. Category 1 classifies the sentence as fact, stated conclusion, definition or question answered immediately. While Category 2 classifies the sentence as question requiring student to analyze data, statement requiring student to formulate conclusion, direction to student to perform and analyze some activity and solve problems or question to arouse student answer and not answered immediately. This procedure is based on the Romey's procedure. The result is interpreted as follows: the average score is 1; if the student involvement index is greater than one, then there is higher student involvement; if it is less than 1, then the student involvement is low.

Communication Index tells the readability of the module. This is the ratio of the sum of the product of the number of times the unclear word appeared in the sample and the number of students who found the word unclear and the product of the number of sample words and the number of readers. The range of acceptable values for communication index is between 0 and 0.01 inclusive.

Grade Level tells the level at which the module is more appropriate to. This is done by plotting the average number of sentences from the three sample pages of the module: first, middle and last, per hundred words against the average number of syllables per hundred words on the same pages in the Fry Graph of Estimating Reading Ages as shown in Figure 3.

RESULTS AND DISCUSSION

This part presents the discussion of results of the study.

SOP1. What are the feedbacks of experts on the first draft of the developed instructional material?

The feedbacks of the experts on the first draft of the module were as follows:

1. A good introduction has been given that will prepare the learners to understand and grasp the subject matter. The author uses as an introductory matter the popular

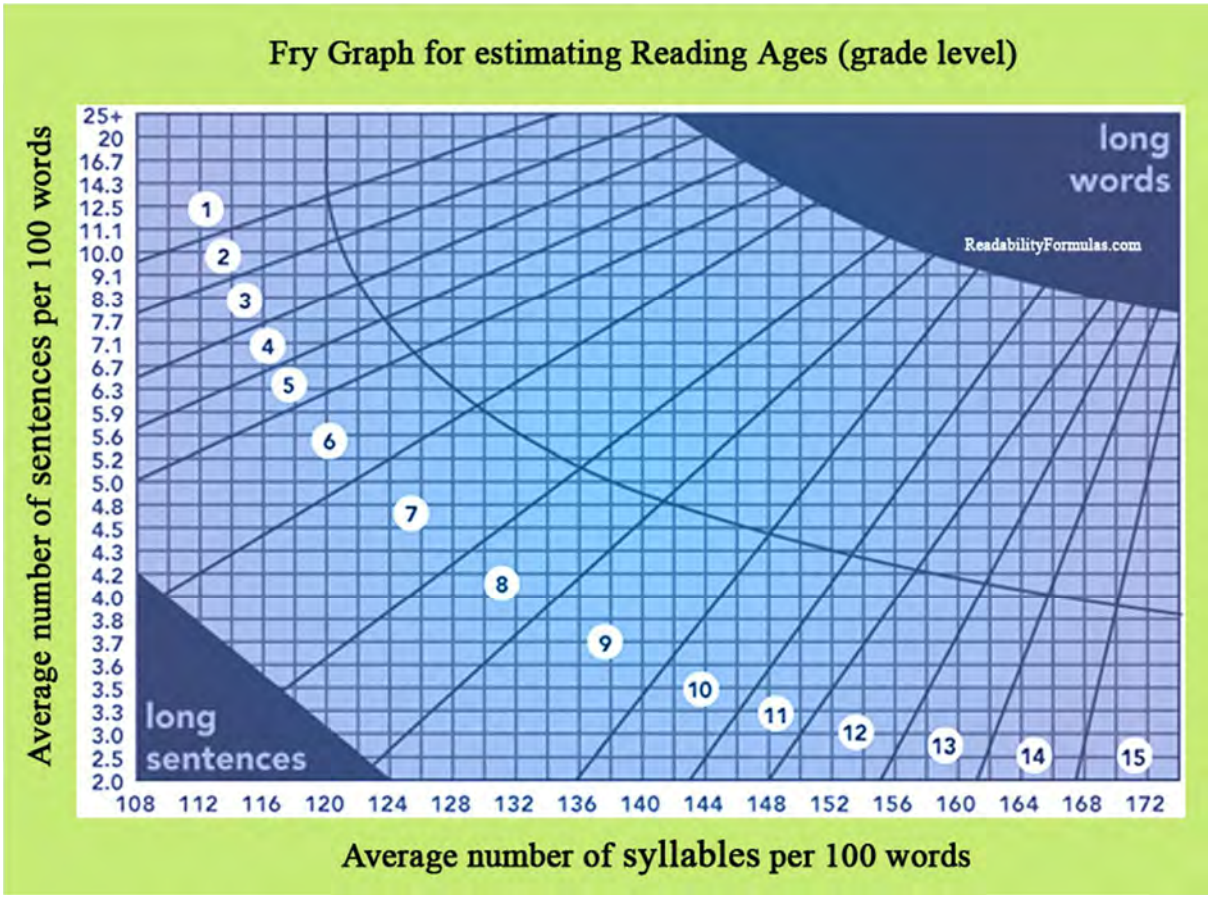

Figure 3. Fry graph for estimating reading ages.

networking business, especially of food supplements, of which all learners are familiar. The intention is to bring into their mind the concept that exponential and logarithmic functions are part of our daily lives.

2. The module has two subtopics: Exponential functions and Logarithmic functions, with two lessons and four lessons respectively.

3. Objectives are clear since in each topic the main objectives are to make learners understand the subject matter and be able to apply the knowledge gained to other situations, in mathematics the application is mainly to be able to solve mathematical problems involving the subject matter in question.

4. The sequence of the lessons is logical.

5. Good presentation: the teacher gives the students a set of solved mathematical problems to let them study and come up with what they think would be the steps/rules in solving such problems. Furthermore, the module provides students with the guideline of how to write their quarterly research paper thus introducing students to scientific writing.

6. The module does not indicate to which class the lesson is intended.

7. Although it is clear from the context that the module is for students who have mastery in functions and graphs, correct use of concepts would be appropriate.

For example in Lesson 1

An introduction to exponential functions is presented by a mathematical growth of sellers in a networking business. But the table of values (Table 1) indicates the variables x and y without any prior explanation of their use. I think, instead of using *x* and *y*, it was supposed to be presented this way.

From here, there could be some explanation that the number of sellers is a function of time, so that in Activity 1 #1 the variables *x* and *f(x)* would clearly be understood.

1. There are good number of exercises, something which is good. But it should be stated whether they are intended as assignment for a group or individual; whether they are to be done inside the classroom or as home work; whether the exercises will be submitted for evaluation or not.

2. If the exercises are meant to be submitted for evaluation in the class then time limit should be indicated.

3. Scoring guide for problem solving should be available.

4. Scoring guide for the quarterly project should be

Table 1. Variables x and y without any prior explanation of their use.

Time (t)	0	1	2	3	4
No. of sellers at time t	1	2	4	8	16

available.
5. There is no time frame both for the main topic in general, and for each lesson in particular, unless it is implied that one lesson is equivalent to a one-hour meeting. If it is so, there is a need to adjust the class activities especially the exercises to fit a one hour time frame. As it is now, one lesson is going to take more than one hour.
6. There should also be time limit for studying the sample solutions to complete one activity.
7. Most of class activities are teacher-given. May be the teacher could also focus on activities which are more engaging to students, that will lead students make new discoveries or widen their perspective on the subject matter.

SOP2. What is the student involvement index of the module?

As shown in Table 2, the student involvement index of the module is the ratio of the Category II and Category I. Category II has a total of 54 sentences consisting of 5 questions requiring students to analyze data, 14 statements requiring students to formulate conclusion, 34 statements directing students to perform and analyze some activities and solve problems and 1 question arousing student to answer or not to answer immediately. Category I has a total of 46 sentences consisting of 30 statements of facts, 5 stated conclusions, 10 definitions and 1 question requiring an immediate answer. The computed student involvement index is 1.17. This indicates that the module has high student involvement. This means that the module highly encouraged and moved students to perform the activities, analyze and solve problems and make necessary conclusion when the activity in the module requires it.

SOP3. What is the communication index of the module?

Table 3 shows that the unclear words found by students. The sum of the product of the number of times they appeared in the sample and the number of students who found them unclear is 50. This product is necessary for the computation of the communication index, which is the ratio of the sum of the product of the number of times the unclear word appeared in the sample and the number of students who found the word unclear and the product of the number of sample words and the number of readers. This study involved 300 sample words and 5 readers. Thus the communication index of the module is as shown in Table 4.

The communication index of the module is 0.03. This value falls out the range of acceptable communication index. This indicates that the words used in the module may not be appropriate to their grade level. The users may found the words difficult that is why when these words were used in sentences they did not fully understand. The result also tells that the researcher should review the word-sentence list form to refrain using those words the students found difficult and revise sentences that are vague and hard to understand.

SOP4. What is grade level of the module?

Table 5 shows the average of the number of sentences and number of syllables of the three sample pages of the module. The average number of sentences is 9.33 and the average number of syllables is 172. Plotting these averages in the Fry graph for estimating reading ages yields as shown Figure 4.

Figure 4 shows that the point of intersection of the two red lines is approximately between the boundaries of grade 12 and the area within the boundaries of grade 13. This indicates that the developed module is suited for the use of grade 12 or college students. This result also explains why the communication index of the material falls out of the acceptable range. The module was intended for the use of grade 11 students but it turned out to be an acceptable module for either grade 12 or college students.

SOP5. What is the description of the revised module?

Based on the results of the readability test, the researcher completely changed the mode of presentation but still based the material in the Understanding by Design lesson plan. The researcher ensured that the module would be appropriate to the level of students. The revised module was composed for five lesson; each lessons contains the structure of the revised module (Table 6).

RECOMMENDATIONS

Based on the results of the study, the recommendations are as follows:

1. The material should undergo readability test again to ensure its readability and appropriateness to the users.
2. Summative evaluation is suggested to determine the effectiveness of the material to the teaching and learning process.
3. Future researchers and instructional material writers may produce modules of the same design but, exploring on other topics in math.

Table 2. Student involvement index of the module.

Category	Number of Sentences										Total
	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10	
I											
1. Facts	3	6		6		1	2	3	3	6	30
2. Stated Conclusion	1		1					2	1		5
3. Definition	1					6	1			2	10
4. Questions answered immediately								1			1
Total											46
II											
5. Questions requiring student to analyze data								1	3	1	5
6. Statement requiring student to formulate conclusion	1		3	2	3		3	1		1	14
7. Directions to students to perform and analyze some activity and solve problems	3	4	6	2	7	3	4	2	3		34
8. Questions to arouse student's answer and not answered immediately	1										1
Total											54
Student involvement index of the module											1.17

Table 3. Table of the product of the number of times unclear words appeared in the sample and the number of students who found the words unclear.

Unclear words	No. of times the word appeared in the sample (X)	No. of students who found the word unclear (F)	FX
Trivial	1	3	3
Plausible	1	5	5
Logarithm	3	4	12
Logarithmic	4	4	16
Exponential	2	4	8
Incentive	3	2	6
Total	14		50

Table 4. Communication index of the module.

Communication Index	Interpretation
0.03	Not Acceptable

Table 5. Module grade level.

	Number of sentences	Number of syllables
First page	8	167
Middle page	10	196
Last page	10	155
Average	9.33	172.67

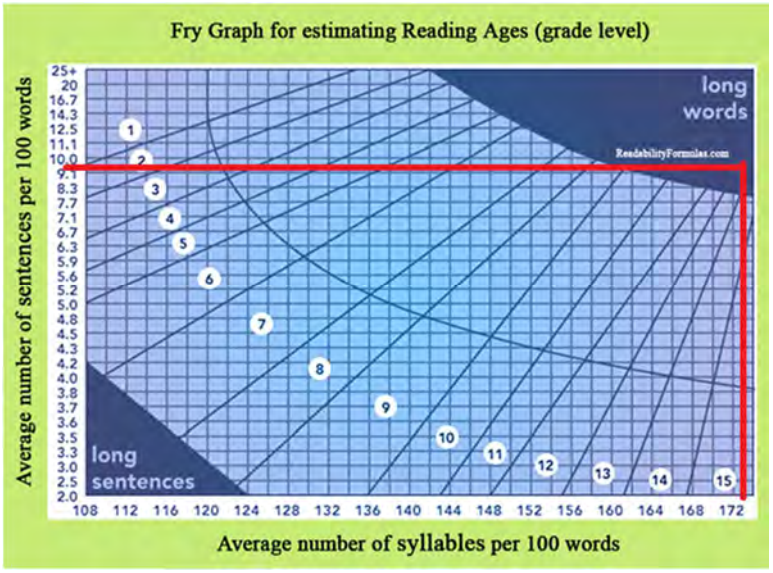

Figure 4. Grade level of the module.

Table 6. Module structure.

Lesson	Objectives	Content	Activity
Lesson 1. Exponential Function	At the end of the lesson the students should be able to: 1. Define an exponential function and; 2. graph the exponential function.	1. Definition of exponential function 2. Mathematical definition of exponential function 3. Properties of an Exponential Function	1. Group work: forming an exponential function using the concept of binary fission of bacteria 2. Individual work: graphing exponential function with b>0 3. Individual work: graphing of exponential function with b<0 4. Group Work: research project observing the a particular of bacteria that grow or decrease exponentially. 5. Presentation of the research project
Lesson 2. Exponential Equation	At the end of the lesson the students should be able to solve exponential equation.	1. Solving exponential equation	1. Group work: solving exponential equation 2. Group work: using the information gathered in research 1 they must present the following: a. Identify the point or interval where in the population of a culture of bacteria reaches the maximum number. b. Identify the point or interval where in the population of a culture of bacteria starts to decrease. c. Enumerate what happens to the culture of bacteria when it reaches the maximum number. d. Enumerate what happens as the population of bacteria decreases.
Lesson 3. Logarithmic Function	At the end of the lesson the students should be able to: 1. define an logarithmic function and; 2. graph the logarithmic function.	1. Definition of logarithm 2. Definition of logarithmic function 3. Properties of logarithmic functions	1. Group work: graphing of logarithmic function with base greater than 1 2. Group work: graphing of logarithmic function with base less than 1

Table 6. Continues.

Lesson Evaluating Logarithms Using Exponential Equation	4. At the end of the lesson the students should be able to: 1. convert exponential form to logarithmic form and vice versa; 2. solve logarithms using exponential equation and 3. solve logarithmic equations using exponential equation.	1. Steps in Evaluating Logarithms	1. Individual work: evaluating logarithms using exponential equation
Lesson Laws of Logarithms	5. At the end of the lesson the students should be able to: 1. know the laws of logarithms 2. apply the laws of logarithms in solving equations	1. Laws of Logarithms	I. Individual work: expressing in terms of single logarithm II. Individual work: expressing logarithm as sum and/or difference III. Individual Work: Converting Logarithms of Different Base to Common and Natural Logarithms IV. Individual Work: Solving Logarithmic Equations V. Group work: preparing a written report integrating Research Projects 1 and 2 using the following format: VI. Introduction VII. Method of Reproduction or Decay of a Culture of Bacteria VIII. Mathematical Model or Equation Representing the Growth or Decay of the Culture of Bacteria IX. Benefits From Growth or Decay of the Culture of Bacteria X. Danger from Growth or Decay of the Culture of Bacteria XI. Recommendation XII. Personal Insights

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