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Development and Validation of an Interactive E-Module in Triangle Inequality and Its Theorems for Grade 8 Learners

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Abstract
This research focuses on the development and validation of an interactive e-module designed to enhance understanding of triangle inequality and its theorems among grade 8 learners. Employing the ADDIE development process, the study utilizes Microsoft PowerPoint Slide Presentation Software, incorporating hyperlinks and triggered animations in developing the material. The objective is to validate the developed material and assess the difference in mean scores of achievement tests between groups with and without intervention. Employing a quasi-experimental design, the study compares achievement levels of control and treatment groups, with evaluation conducted by the panel of evaluators. The interactive e-module's reliability and validity are confirmed, indicating its suitability for distance learning. Implementation occurred in a specific grade 8 class, while a traditional module served as the control. The study, following a quasi-experimental design, compares achievement levels between groups using a teacher-made achievement test. Evaluation involves an assessment by experts and a post-test to measure learners' conceptual understanding. The developed e-module receives positive feedback from evaluators and learners, with mean scores meeting predefined criteria. The experimental group demonstrates higher proficiency compared to the control, supported by statistical analysis rejecting the null hypothesis. Learners perceive the interactive e-module as beneficial for understanding, engagement, and promoting independent learning. However, suggestions for technical improvements and enhancing content comprehension are highlighted for future refinement. Overall, this developmental research contributes valuable insights into the utilization of interactive e-modules as it enhances mathematical understanding among grade 8 learners.
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1. Introduction

Theorems on Triangle Inequality play a significant role in Grade 8 mathematics education by shaping learners' understanding of geometric concepts and inequalities. Understanding the Triangle Inequality is crucial for Grade 8 learners as it forms the basis for reasoning about geometric relationships within triangles. Developing and constructing knowledge and understanding this concept through collective argumentation is essential for learners' mathematical growth (Uygun & Akyuz, 2019).

The generalizations of the triangle inequality illustrate the profound notions of mathematics epistemology, emphasizing the creation of general concepts on higher levels of abstraction that preserve the unity of mathematics (Abramovich & Grinshpan, 2008). This understanding contributes to the broader goals of the Grade 8 Mathematics Curriculum by providing learners with a deeper insight into the interconnectedness of mathematical concepts and the development of abstract reasoning skills.

Moskowitz (2014) showed that triangle inequality is a fundamental concept in mathematical reasoning and analysis for some natural homogeneous norms in mathematical spaces. This concept helps learners in Grade 8 Mathematics to understand and use inequalities in different mathematical situations.

The current state of mathematics education for Grade 8 learners in the context of the Triangle Inequality and its Theorems presents several challenges. The diagnostic report on Annual National Assessments (ANA) in Mathematics revealed that a significant number of learners in early grades need to reach the expected levels of mathematical competencies (Govender et al., 2019). This indicates a gap in foundational mathematical understanding, which may extend to the understanding of concepts such as the Triangle Inequality.

Indeed, mathematics is a challenging subject for many learners even in traditional classroom settings. The pandemic has made it harder for learners who rely on modules to study mathematics (Meniano & Tan, 2022). Teachers are unsure about how well learners understand mathematical concepts since they have limited access to guidance and feedback from their instructors (Viamonte, et al., 2021). Learners have to rely on their self-directed learning with printed modules that may not provide enough explanation or clarification.

The development of an interactive e-module aims to address these challenges by providing a comprehensive, learner-centered approach to mathematics education. It is designed to bridge the gap in foundational mathematical understanding, particularly in the area of Triangle Inequality and its Theorems. This development caters to the current educational landscape, particularly in the context of distance learning during the COVID-19 pandemic.

According to Purnamasari et al. (2020), E-modules belong to interactive teaching sources that are capable of facilitating learners to learn independently. The prevalent use of distance learning has necessitated the adaptation of educational resources to virtual platforms, and the e-module provides an effective means of delivering mathematical content to Grade 8 learners in this modality.

The researchers follow the ADDIE development process in developing the material. This iterative process includes Analysis, Design, Development, Implementation, and Evaluation. Microsoft PowerPoint Slide Presentation Software was used as the tool in developing the material. The researchers utilized the interactive features of MS PowerPoint – hyperlinks and triggered animations.

The e-module leverages electronic-based self-learning, allowing learners to interact with the content in a way that responds to their input. This fosters an engaging learning environment where learners can actively participate in learning activities during distance instruction. Moreover, the e-module offers visual information through a wide variety of media types, simulating education in a remote learning environment. This approach not only enhances the understanding of mathematical concepts but also promotes self-directed learning, which is crucial in the current context of distance learning. By providing clear explanations and clarifications, the e-module aims to alleviate the difficulties faced by Grade 8 learners in studying mathematics, especially during the pandemic. In their study, Dankbaar et al. (2017) demonstrated how interactive e-modules can enhance learners' engagement and learning outcomes.

The main objective of this study is to develop and validate an interactive e-module in Triangle Inequality and its Theorems for Grade 8 learners. Specifically, it aims to: validate the development of the material and see whether a significant difference exists in the mean scores of the achievement tests between two groups - one with intervention and one without. It also aims to gather learners' perceptions of the developed interactive e-module.

The study utilized a quasi-experimental research design to compare the achievement levels of the control group and the treatment group. The validation process involves a thorough evaluation by a panel of experts which ensures the reliability and validity of the e-module, indicating that it was suitable as a learning material to assist learners in distance learning, particularly in the context of the distance learning setup during the pandemic. The positive outcomes and improvements resulting from the implementation of the interactive e-module are evident in the study's findings. The e-module was found to be suitable for distance learning and was validated and categorized effectively based on the variance of the experimental and control groups.

This study focuses solely on the development and validation of the interactive e-module in triangle inequality and its theorems for grade 8 learners. The developed material was implemented in a grade 8 STE-A only while STE-B learners take the traditional module as instructional materials. The researchers do not have control over the learners' responses to the achievement test for both groups. The pretest is integrated into the interactive e-module, it is not used to gather data for any statistical analysis for comparison. Only the post-test was used to test the achievement level of different groups.

2. Methodology

This study is developmental research and the research design used is a quasi-experimental research design. It is quasi-experimental since the study aims to compare the achievement level through the teacher-made achievement test (post-test) of the two groups of participants: the control group and the experimental group.

The Evaluation Rating Sheet adapted from the Department of Education, DM No. 441 s. 2019 is used to evaluate the entirety of the developed interactive e-module done by the panel of evaluators. It evaluated the factors of Content Quality, Instructional Quality, and Technical Quality of the interactive e-module. The data gathered from the evaluation was interpreted through the given condition on the adapted Evaluation Rating Sheet. The remarks of each factor were either "passed" or "failed". To pass each criterion, a resource must score at least 30 points out of a maximum of 40 points for Content Quality and Instructional Quality, and at least 39 points out of a maximum of 52 points for Technical Quality. The evaluation rating sheet has an additional criterion called "Other Findings" which requires 16 points out of a maximum of 16 points to have a remark of "passed". If the criterion has not reached the minimum required scores, then the remark is "failed" which means that the developed material needs to be revised.

The teacher-made achievement test (post-test) is also used in the study. This test aims to measure learners' conceptual understanding of the subject matter which consists of fifteen (15) items of questions that are face, content, and construct. In interpreting the level of achievement of the learners on their performance scores on the achievement test (post-test), mean scores, a total of fifteen (15) points is the highest score given and zero (0) is the lowest score. The interpretation was based on the Department of Education's norms in interpreting the level of proficiency of a learner (DepEd Order no. 73 s. 2012) were used and modified in this study. The table below shows score intervals and their corresponding interpretation used in this study.

Table 1. Interpretation of Learners' Level of Achievement Test Scores

Score Interval	Transmuted Grade	Interpretations
14 – 15	90%	Advanced
11 – 13	85% – 89%	Proficient
8 – 10	80-84%	Approaching Proficiency
5 – 7	75-79%	Developing
0 – 4	74%	Beginning

In testing the difference of the means of the two groups, an independent two-sample t-test is used. It is an inferential statistical test that determines whether there is a statistically significant difference between the means in two unrelated groups.

Moreover, a perception questionnaire was used to describe the learners' perception of (1) certain ways in which the interactive e-module helped them understand the concepts of Triangle Inequality and its Theorems; (2) what they liked in the interactive e-module; and (3) their difficulties in doing /using the interactive e-module. It consisted of seven (7) open-ended questions wherein the respondents could freely express their opinions in English, Filipino, the vernacular, or a combination of such languages. The questionnaire is given to the experimental group through Google Forms. Learners' perceptions were analyzed through a research tool used to determine the presence of certain words, themes, or concepts called thematic analysis.

2.1 Data Gathering Procedure

The data-gathering procedure follows the iterative procedure of the ADDIE Model which involves the process of instructional designing as presented in the figure below. The processes of Analysing, Designing, Developing, Implementing, and Evaluating are not always linear and are repeated steps to consider in the construction of the interactive e-module.

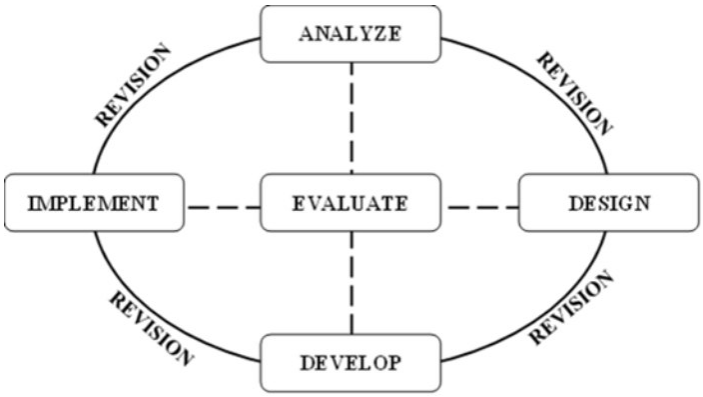

Figure 1. Iterative Process of the ADDIE Model (Branch, 2009)

Analysis Phase. In this phase, the researchers gather information about the learners and the learner's needs. This is also the stage in making decisions on the delivery methods, content selection, construction of learning objectives, and establishing resources and constraints.

Design Phase. Learning contents were sequenced through the construction of storyboards. Writing of scripts and prototyping delivery methods also took place in this phase.

Development Phase. This involves creating, assembling, and organizing the interactive e-module. Audiovisuals are recorded, edited, and produced. Also, in this stage, the interactive e-module is being piloted and evaluated by the panel of evaluators.

Part of the phase of this study is the evaluation of the developed interactive e-module through an evaluation rating sheet which was conducted by the panel of evaluators which included pedagogy/content experts and technology (IT) experts.

Implementation Phase. This is the phase where the interactive e-modules are delivered and accessed by the learners. In this phase, the implementation or the utilization of the developed interactive e-module for the participants took place. After finalizing the developed interactive e-module, this has been handed over to the mathematics subject-teacher of the experimental group to be used and implemented during classes (of the participants).

Evaluation Phase. Evaluation intersects with the other stages of the process. There are two types of evaluation: (1) Formative Evaluation, which describes the examination that is done throughout the other four stages of the process to enable researchers to recognize potential barriers, respond to the challenges, and avoid repeating mistakes; and (2) Summative Evaluation, which focuses on the outcome of the project during the implementation phase.

The last phase of this study is the evaluation of the developed material to learners or the evaluation stage of

the ADDIE development process. In this segment, the same achievement test is given to both groups of participants (control and treatment) through Google Forms to see the difference and interpret the achievement level of both groups toward the developed interactive e-module. The treatment group of participants was then given a perception questionnaire that tackled their perception of how the developed interactive e-module was.

3. Results and Discussions

3.1 Development of Interactive E-Module

The development of the interactive e-module in Triangle Inequality and its Theorems for Grade 8 learners follows the ADDIE development process which includes Analysis, Design, Development, Implementation, and Evaluation. A discussion of the process for each stage is presented in this section.

Analysis Stage Results. In the analysis stage, the researchers made thorough searches on the learners who utilize the developed interactive e-module. The researchers gathered information about the learners' demographic profiles as well as the learners' needs academically, especially in Mathematics. In this stage, the researchers decided that the delivery method of the interactive e-module must be a one-time download through link share to cater to the learners' limited internet connectivity. The content of the interactive e-module is also identified in this stage. The researcher also has decided to utilize the Version 5 Self-Learning Module (SLM) developed by the Department of Education – Division of Gingoog City for the construction of objectives as well as the content of the developed interactive e-module. These SLMs are the ones currently utilized by the learners under the Department of Education – Division of Lanao del Norte.

Design Stage Results. In the designing stage, storyboarding, prototyping of delivery mode, and script writing took place. In doing so, parts of the interactive e-module are identified according to how learning contents were sequenced in the Version 5 Self-Learning Module (SLM) developed by the Department of Education – Division of Gingoog City. Two self-learning modules were retrieved by the researchers. However, the two modules were integrated into one interactive e-module during the designing stage. The reason is for learners' convenience in downloading the material.

Development Stage Results. Creating, assembling, and organizing the interactive e-module took place in the development stage. The developers of the interactive e-module are the researchers of this study. Microsoft PowerPoint Slide Presentation Software was used as the tool in developing the material. The researchers utilized the interactive features of MS PowerPoint – hyperlinks and triggered animations. Hyperlinks are useful for navigation; triggered animations are useful for showing or hiding objects on a slide. These two elements are used together to develop the interactive e-module. The researchers followed the design plan as they developed the material. The script written during the design stage for audio narrations was edited, recorded, and integrated on each slide of the interactive e-module following the DepEd Self-Learning Modules (SLM).

Implementation and Evaluation Stage Results. The evaluation stage intersected with each of the other stages of the process. Researchers were able to recognize barriers, respond to the challenges, and were able to avoid repeating mistakes through formative evaluation.

After the interactive e-module was developed, the material went through evaluation using an evaluation rating sheet to gain recommendations from experts for the possible use of the developed material in a public school. The evaluators of the developed interactive e-module include the two panel members of this study, one pedagogy expert, one content expert, and one information technology (IT) expert. The table below shows the ratings of the evaluators of the developed interactive e-module.

Table 2. Summary of Evaluation of the Developed Interactive E-Module

Evaluators	Factor A	Factor B	Factor C	Factor D
Panel Member 1	36	38	48	16
Panel Member 2	37	35	48	16
Content Expert	36	38	48	16
Pedagogy Expert	38	37	45	16
IT Expert	40	36	48	16
Mean	**37.4**	**36.8**	**47.2**	**16**
Remarks	**Passed**	**Passed**	**Passed**	**Passed**

The table 2 shows the mean scores of the evaluators of each factor of the evaluation sheet. The average score of the Factor A – Content Quality is 37.4 which is marked as "passed" by the criteria of the evaluation sheet. In Factor B – Instructional Quality, the average score is 36.8 which is marked as "passed" by the criteria of the evaluation sheet. Also marked as "passed" by the criteria of the evaluation sheet is Factor C - Technical Quality with an average score of 47.2. Lastly, Factor D – Other Findings has an average score of 16 which is also marked as "passed".

After gaining the approval of the developed interactive e-module for possible use in public schools, it was implemented to 37 Grade 8 learners in the experimental group but only 26 of them responded. During the implementation, the interactive e-module was handed over to the math teacher of the experimental group to be

forwarded to the learners. The learners used the interactive module for two weeks instead of the printed self-learning modules (SLM).

3.2 Interpretation and Comparison of Achievement Level (Post-Test)

Table 3. Interpretation of the Achievement level of Two Groups

	Experimental Group	Control Group
Overall Mean	10.19	8.26
Transmuted Grade	80-84%	80-84%
Interpretations	Approaching Proficiency - Proficient	Approaching Proficiency

The table 3 shows the interpretations of scores of the two groups. It is based on the Department of Education's norms in interpreting the level of proficiency of a learner (DepEd Order no. 73 s. 2012). The mean score of the experimental group is 10.19 which falls to a transmuted grade of 80-84% is interpreted as "Approaching Proficiency – Proficient". While the mean score of the control group is 8.26 which falls to a transmuted grade of 80-84% is interpreted as "Approaching Proficiency".

Moreover, this study claims that there is a significant difference of the mean scores of achievement test (Post-test) between the control group who used the DepEd SLM and experimental group who used the interactive e-module in Triangle Inequality and its Theorems of Grade 8 learners.

Table 4. Comparison of the Achievement Level of Two Groups (Pooled Variance T-test)

	N	Mean	S.D.	M.D.	Pooled Variance	S.E.	T	P-Value	Remarks
Experimental Group	26	10.19	3.67	1.93	12.22	0.961	2.013	.0495	Significant
Controlled Group	27	8.26	3.32						

*level of significance: $\alpha = .05$

The table 4 presents the pooled variance t-test in comparing the achievement level of the experimental group and control group. Results show that the null hypothesis is to be rejected since p-value (.0495) is greater than the level of significance ($\alpha = 0.05$). This concludes that there is a significant difference in the mean scores on the achievement test (Post-test) between the control group who used the DepEd SLM and the experimental group who used the interactive e-module in Triangle Inequality and its Theorems of Grade 8 learners.

3.3 Learners' Perception towards the Developed Interactive E-Module

In two weeks, Grade 8 learners from the experimental group were exposed to the developed interactive e-module in triangle inequalities and its theorems. Learners from this group were tasked to use the interactive e-module and answer all the activities embedded in the developed material including the teacher-made achievement test at the end of the module. After finishing all the activities and tests embedded in the interactive e-module, the learners answered open-ended perception questions. The researchers clustered the questions into three parts: (1) certain ways in which the interactive e-module helped them understand the concepts of Triangle Inequality and its Theorems; (2) the things that they liked in the interactive e-module; and (3) their difficulties in doing /using the interactive e-module. This section discusses the generated themes and codes from the learners' responses on their perception of the interactive e-module.

Codes Generated from the Theme "Understanding the Lesson". Five emerging themes encapsulated the perceptions of the learners with the interactive e-module. "Understanding the lesson" from their responses refers to the learners' engagement with the content of the lessons as embedded in the e-module. The theme is composed of the following codes that describe their learning process and experience as they engaged with the material: 1) making the lessons easier, 2) positive challenge, 3) self-assessment, and 4) a better understanding of the lesson. The learners experienced ease in understanding the lesson compared to the printed modules because of the audio-visual presence of the e-module. A learner described this experience:

"*During the time that I answered the activities in e-module, I was amazed because aside from the visual presentations there is also an audio where in s/he explained to us the examples given in that activities. The audio and visual presentations are a big helped in understanding the topic. It has a big impact for the students*."

Rasul et al. (2011) argued that audio-visual aids are the most effective tool for enhancing teaching and knowledge dissemination. Therefore, technical devices have a significant impact and a dynamic information system.

Codes Generated from the Theme "Engaging the Learners". The learners were also engaged with their use of the e-module and the theme "Engaging the Learner" emerged from the learners' responses. It refers to how learners got engaged in the lesson through the interactive e-module. "Fun learning", "students' interest", and "interactive" were coded describing their perception of the e-module in terms of engagements. Dankbaar et al. (2017) highlighted the ability of interactive e-modules to stimulate learners' engagement and improve learning comprehension. Learners pointed out so many parts of the material that they liked and perceived to be engaged

through it. A learner describes the part of the interactive e-module that this learner likes and how the material encouraged this learner to get engaged in utilizing the developed interactive e-module.
"*the part that I like in the e-module is in the part of drawing and measuring of our own triangles because it help us to practiced on how to get the exact measurement or angles of the triangle.*"

Learners perceived that interactive e-module engages them through the embedded practice exercises. It allows the learners to get motivation from the interactive activities and be able to learn on their own. These perceptions entail another theme emerged.

Codes Generated from the Theme "Independent Learning". The interactive e-module also promotes independent learning that is way different from the printed module. Learners described that they could get back to the part where they wanted to learn more because of the e-module's features that allows them to do so. A learner also mentioned that it can also be a help to those learners who prefer to study alone, and it teaches them to be responsible in their academics and get used to it.
"... it teaches learners to learn how to learn while in self-learning that he or she could understand and to get used to it"

Moreover, learners perceived that the interactive e-module really makes them solve problems on their own and helps them to solve confidently. This affirms Purnamasari et al. (2020) that indeed e-modules facilitate learning independently. Learners' learning outcomes can be maintained and improved by using e-modules.
"... it really can make you to solve the problems by your own and it helps us to solve it confidently"

Codes Generated from the Theme "Improving the E-Module Technicalities". However, the learners also gave some insights on improving the e-module technicalities. The following were coded from their responses: "improve audio quality", "access difficulty", and "file size". The learners have this negative perception of the developed material. Some of the learners had really struggled in accessing and downloading the interactive e-module. Unstable internet connection and the material's file size contribute to the learners' unavailability to access the developed interactive e-module.
"The only problem in using the e-module is the availability of the internet connection and there are times also that the audio is not present."

But despite to that fact, the researchers still noted that seven learners have no problem with the developed e-module. Learners have not encountered any problems or struggles in the developed material.
"I don't have any problems or any suggestions in E-module since it's already good for me"
"For me, I just want more e-modules to be given because in that way, I can learn more and improve my knowledge."
"I don't think there are some things that needed to be improved."

Codes Generated from the Theme "Improving the Lesson Content". The learners also pointed out some content that was hard for them to understand. Hence, the theme on "improving the lesson content". Codes include "more and improving examples", "clarity of instructions", "content difficulty", and "clarity of lesson". Learners got confused about some of the parts of the interactive e-module. It is also perceived by the learners that some parts of the interactive e-module were hard to understand.
"The part that I like in E-module is the discussion and what I don't like is sometimes in every activity given is it felt hard to understand"

Overall, there are positive learners' perceptions coded into themes that are helpful in this study to see how learners appreciate the developed interactive e-module. Negative learners' perceptions towards the developed interactive e-module were also significant for the researchers to determine the gap not met during the development of the material and also to see what has to be improved in the interactive e-module.

4. Conclusions

Based on the above findings, the following conclusions were drawn. The developed interactive e-module gained recommendations from experts for the use of the developed material in public schools. The developed material went through a thorough evaluation and resulted in positive recommendations.

There is a significant difference in the mean scores on the achievement test (Post-test) between the control group who used the DepEd SLM and the experimental group who used the interactive e-module in Triangle Inequality and its Theorems of Grade 8 learners.

Learners positively perceived that the interactive e-module helped them to better understand the lesson, engage them in the lesson, and promote independent learning that is way different from the printed module. However, the learners also gave some insights on improving the e-module technicalities and pointed out how to improve the lesson content because some of it was hard for them to understand.

5. Recommendations

After a thorough analysis of the data, the researchers made the following recommendations:

1. The achievement test should have a dry run before implementation for both pretest and posttest.
2. The developed interactive e-module is recommended to be reimplemented or improved based on the

results of this study.

3. Teachers who plan to use interactive e-modules as instructional material for distance learning modality must monitor the learners along the journey of implementing the interactive e-module. This is to accommodate learners' clarifications and to provide clear instruction.
4. The developed interactive e-module may also be applied to other year levels and schools. Its effectiveness in improving learning and teaching in mathematics will provide solutions to the problems in learning in a new normal setting.
5. To future researchers, it is recommended that further studies be conducted on other topics and other subject areas to test the validity of the effectiveness of the Interactive E-Module in the improvement of learners' academic performance. It would be best if the conduct of the study would take a more extended period and with larger respondents.
6. Include performance tasks and the Pretest-Posttest in measuring the level of achievement of the learners.
7. In the content of the interactive e-module, it is recommended to emphasize proving theorems. Embed interactive activities that cater more on proving.
8. Multimedia evaluation for the interactive e-module is recommended and observed "Multimedia Learning Theory" which describes the use of multiple simultaneous techniques in instructional message design, such as combining narration and visuals in a presentation (Ramlatchan, 2019).

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