DEVELOPMENT AND EFFECTIVENESS OF A RESOURCE-BASED COURSE GUIDE IN TEACHING ADVANCED ENGINEERING MATHEMATICS COURSE

Harold Jan R. Terano[1], Leonila B. Barbacena[2]

[1] *Professor I, Camarines Sur Polytechnic Colleges, Philippines*
[2] *Professor VI, Bicol University, Philippines*

ABSTRACT

Resource-based course guide is an instructional material incorporating resource-based learning that emphasizes the use of resources in support of student-centered learning. This study was focused on the development and effectiveness of a Resource-Based Course Guide in Teaching Advanced Engineering Mathematics. The features of the instructional material include the use of varied learning resources, the use of student-centered and collaborative learning strategies, and the use of appropriate computer applications. The findings of this study based on the evaluation of jurors revealed that the developed course guides are all rated very satisfactory along the various aspects: alignment, content, pedagogical components, and technical aspects. The study employed a quantitative method utilizing a pre-experimental design. The study utilized a pretest and posttest for the pre-experimental group of 36 students. Results found a significant difference in the mean scores in terms of the pretest-posttest conducted and thus indicate that the intervention had caused the difference in the mean of the experimental class.

Keyword: *resource-based learning, course guide, advanced engineering mathematics, instructional material*

1. INTRODUCTION

Education is critical for everyone's success today and in the future. It is quite beneficial in dealing with life's obstacles and hardships. Knowledge, skills, and values acquired during the educational process enable individuals to be self-assured in their own lives. This is the most important component of an individual's development to achieve a better future. The major problems that should be addressed in every educational institution for a better outcome for each individual are advancing knowledge, skills, and values. How successfully an educational institution creates and administers the whole curriculum for a certain program might impact students' learning results. The effectiveness with which an educational institution designs and implements the whole curriculum for a particular program can influence the learning outcomes for students (Terano, 2019). As a result, higher education institutions must be adaptable enough to provide the essential learning to prepare students to tackle new trends in learning and education as a whole.

The development of a nation gives importance on education as an important tool. It may act as a catalyst for economic development, improving living conditions. Quality and quantity of education are key components of the idea that education is a growth-engine (Olaniyan & Okemakinde, 2008). The goal of academia is to restore the standard of fundamental education throughout all subject areas, but especially in science and technology. Countries that seek to raise the standard of living for their citizens must use science and technology to their advantage in order to become more competitive (Ibe, 2012).

The development of engineering education, particularly in the United States, has been fueled by a number of difficulties. These issues include dwindling student enthusiasm in engineering (Melsa, 2007), decreased pre-college math and science success nationally (Tran & Nathan, 2010), and a lack of technical literacy (Pearson & Young, 2002). As a result, emphasizing pre-college education becomes a different strategy to address issues with science, technology, engineering, and mathematics (STEM) education (Honey et al., 2014). In the engineering education, educators have to perform their major responsibilities in molding the knowledge, skills and attitude of the students who can possess the necessary competencies in their chosen field of engineering studies.

The improvement of students' knowledge and abilities is a concern in Philippine engineering education as well. Because they lack the necessary core competences or emotional maturity, high school graduates are not adequately prepared for postsecondary education according to K–12 program implementation (DepEd, 2010).

The purpose of undergraduate engineering education is to prepare graduates for graduate engineering study, to prepare them to contribute to engineering practice by learning from professional engineering assignments, and to lay a foundation for lifelong learning and professional development in support of changing career objectives, such as being knowledgeable, effective, and responsible members of the engineering profession and in society (Cranch, 1986). The purpose of engineering education is to equip students with a solid foundation of preprofessional engineering skills and in-depth technical knowledge (Crawley et al., 2007). For a comprehensive teaching-learning process to take place in the classroom, engineering education curricula must be current and innovative. They should offer instructors a larger variety of teaching tactics and pedagogies as well as learning opportunities for students.

It is difficult to effectively implement teaching in the present era with only conventional means because it is always growing more sophisticated and technical. A vast range of educational resources are now easily accessible thanks to modern technology, supporting instructors' efforts in the teaching-learning process. More importantly, curricula for contemporary issues demand that traditional and conventional teaching and learning tools be used frequently and widely jointly (Abolade, 2001).

Education institutions have transitioned significantly from traditional to online learning as a result of the COVID-19 epidemic. However, issues had been faced by the academic institutions, teachers, and students. In this circumstance, the quality of education has been compromised for more than three years. The temporary switch to a different teaching method revealed some drawbacks, including: inadequate facilities for some students; ineffective teacher-student interaction; the impossibility of performing practical applications; a lack of socialization; a lack of learning motivation; and the possibility of deterioration of physical and mental health (Radu eat al., 2020). Due to these problems, a face-to-face mode of teaching-learning is still the best mode of delivery of instructions to the students.

In preparation for the face-to-face instruction, it is necessary also to prepare the instructional materials to be used by the students. It should ensure the active engagement of students to maximize the learning of the students.

Students are directly involved in thinking and problem-solving tasks when learning using active techniques. Less focus is placed on the passive dissemination of knowledge and more on getting students to manipulate, apply, analyze, and evaluate concepts. Activities like pair and small-group discussions, demonstrations, debates, concept questions, and student comments on their understanding can all be considered active learning in lectures. Active learning is referred to as experiential learning when students take on responsibilities that replicate professional engineering work, such as design-implement projects, simulations, and case studies (CDIO Standards 2.0, n.d.). For this to be implemented, various teaching strategies and modes of delivery can be used. One way to support these strategies is to develop instructional materials or resources that will be needed in the delivery of the teaching and learning process in the classroom.

Resource-based learning (RBL) is described as an integrated collection of practices to support student-centered learning in a context of mass education using interactive media and technologies as well as specially tailored learning resources (Ryan et al., 2013). It gives importance on the role of resources in the teaching learning process (Kong & So, 2008). Resources are anything that has the potential to support learning, including media, people, places, and ideas (Hill & Hannafin, 2001). These are important for an effective teaching and learning process. Teachers and educators need direction and the appropriate teaching resources. The fundamental benefit of resource-based learning is that it enables individual students to advance at their own pace yet along a predetermined course (Ramirez, 2016).

In RBL, the teachers act as coaches, facilitators or guides. The teaching is guided by a student-centered approach. The goal is to teach students to find, evaluate and use information to tackle the challenges they encounter in the learning process. Learners take responsibility for their learning through selection of proper resources that are appropriate to the level of their learning, preferences, interests and abilities.

With the current trends in engineering education, it is high time that engineering educators should explore various strategies and instructional means to deliver and address classroom instruction effectively. With this current time, engineering students must possess the necessary and relevant knowledge, skills, and values for the future work they will be facing. To adapt to the changes in technology and the advent of the industry 4.0, engineers have to possess all these skills.

This study is a response to the important role of engineering educators to adapt to the current frameworks and needs of engineering education. To start with this initiative in reforming educational system for engineering, instructional designs and resources should be developed. This present study is an attempt on a development and test the effectiveness of a resource-based course guide in Advanced Engineering Mathematics at Camarines Sur Polytechnic Colleges (CSPC), Philippines. This course in offered to engineering programs during second semester of their second-year ladder. The proposed material is guided by the course description in accordance with the CHED CMO. The researcher, guided with the concepts of resource-based learning, made this research possible for the benefits of the students and engineering education as a whole.

1.1 Objectives

This study aimed to develop and determine the effectiveness of a resource-based course guide in teaching advanced engineering mathematics. Specifically, it sought to address the following objectives: (1) to identify the features of the resource-based course guide, (2) to evaluate the material along its alignment, contents, pedagogical components and technical aspects, (3) to determine the effectiveness of the material.

1.2 Conceptual Framework

The conceptual framework described in Figure 1 explained how this study was undertaken. The development of the IM started on the identification of the topics to be considered and assuring its alignment to the minimum requirements of CHED.

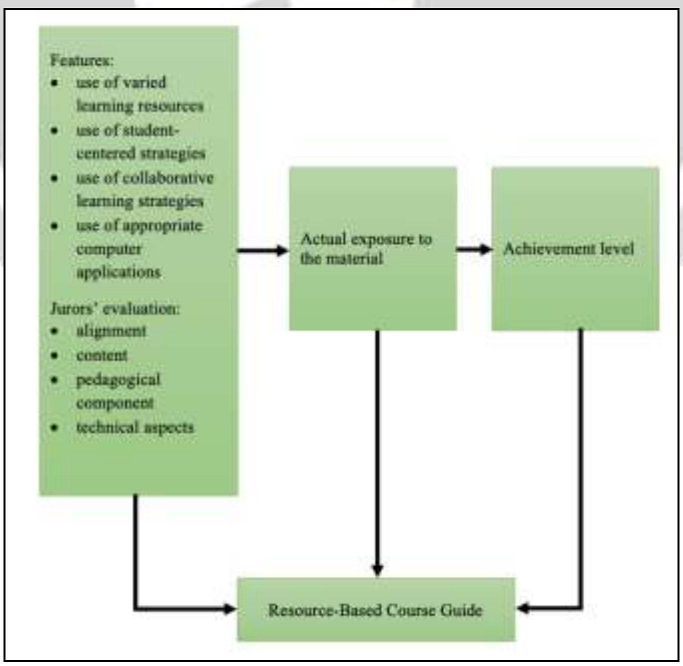

Fig -1: Conceptual Framework

Based on the design of the resource-based course guide, the researcher was able to develop the material. The features of the material include the teachers' role in facilitating understanding of concepts/learning, the use of student-centered strategies, the use of collaborative learning strategies, and the use of appropriate computer applications.

The jurors' validation of the material formed part in its development, and revision was done based on their comments and suggestions. The material was evaluated along its alignment, content, pedagogical components, and technical aspects.

Pretest was facilitated at the start of the study. This is to determine the present achievement of students on multiple-choice and open-ended questions. They were exposed to the material, and after the implementation of the lessons, the class were subjected for posttest to determine the effects of the resource-based course guide to the students along their achievement level.

2. RESEARCH METHODOLOGY

2.1 Research Design

This study used quantitative method utilizing a pre-experimental research design. The statistical, mathematical, and numerical analysis of data gained through surveys, polls, and other sorts of research, as well as the alteration of statistical data that has already been collected using computing tools, are all heavily emphasized in the quantitative method. Quantitative research is concerned with gathering numerical data and applying it to comprehend a particular occurrence or extrapolate it to a larger population of people (Babbie, 2010; Muijs, 2010). On the other hand, pre-experimental design is the simplest form of research design. In pre-experimental designs, either a single group of participants or multiple groups are observed after some intervention or treatment presumed to cause change (Wang & Morgan, 2010).

In this study, a quantitative method was utilized to determine the acceptability of the instructional material using the course guide evaluation instrument and to determine the effectiveness of the instructional material as applied to the pre-experimental group via pretest and posttest using the researcher-made test.

2.2 Research Instrument

A 32-item pretest, 22 multiple choice items and 10 open-ended questions requiring thinking skills was administered among the experimental group. They were subjected to nine (9) lessons covering the whole prelim period of the course utilizing the resource-based course guide. Posttest at the end of the treatment period was facilitated, and mean gain scores were interpreted.

The Course Guide Evaluation Instrument (CGEI) used in this study focuses on the evaluation of the material in terms of alignment, content, pedagogical component, and technical aspects. The validation tool was adopted from the DepEd Guidelines and Processes for LRMDS Assessment and Evaluation (DepEd, 2009). Some indicators especially on alignment was adopted from Nevada Department of Education (Education, 2021) and Instructional Materials Evaluation Tool by Yuson (2018). There were categories enumerated for each sub-parts of the course guide that includes alignment, content, pedagogical component and technical aspects. The number of indicators/items are: five (5) along alignment, seven (7) along contents, eight (8) along pedagogical components, and 22 along technical aspects.

The ratings of jurors to the criteria specified in the Course Guide Evaluation Instrument (CGEI) provided an evaluation of the course guide developed. The scales were adopted the DepEd Guidelines and Processes for LRMDS Assessment and Evaluation (DepEd, 2009).

2.3 Participants

A total of five (5) engineering professors were involved as jurors who evaluated the material. They were requested to evaluate the course guide in terms of its alignment, content, pedagogical component, and technical aspects including accuracy and up-to-datedness of information by accomplishing the Course Guide Evaluation Instrument (CGEI). They were requested to rate the course guide based on the characteristics enumerated under each category.

The subjects were the 36 students of Bachelor of Science in Electronics Engineering enrolled during the 2nd semester S/Y 2022-2023. They are considered homogenous in terms of interest and intellectual capability since they were accepted and grouped in the department to take the course based on their general average in the previous semester.

2.4 Data Analysis

Achievement test was used both as the pretest and posttest purposely to determine if there is an improvement on achievement level of students after exposure to a learning experience as described in the developed course guide. It was composed of two parts; part I was multiple choice questions and part II was open-ended questions requiring thinking skills. The items included in the test covered all the topics considered in the preparation of the lessons in the Resource-Based Course Guide.

The test questions were subjected to face validation. Then, the constructed achievement test were tried to 30 third-year engineering students who had taken and passed advanced engineering mathematics. The students' answers to the first set were subjected to item analysis. A final 32-item questions (22 multiple-choice items and 10 open-ended questions) were formulated.

3. RESULTS AND DISCUSSIONS

3.1 Features of the Resource-Based Course Guide

The developed lessons highlighted features of a resource-based course guide on selected topics in advanced engineering mathematics, such as use of varied learning resources, use of student-centered strategies, use of collaborative learning strategies, and use of appropriate computer applications.

Use of varied learning resources. Learning resources are essential tools being used to help students in learning in diverse ways. These learning resources can be used in different education settings, including traditional classrooms, online learning environments, and blended learning models. In this study, varied learning resources are adopted.

Use of student-centered strategies. These are instructional techniques focusing on the individual needs and interests of students rather than the teacher being the central figure in the classroom. This study employed various student-centered strategies, including gamification, presentation or reporting, and other activities such as seatworks, recitations, quizzes and assignments.

Use of collaborative learning strategies. These are the instructional approach that involves working together to achieve a common goal. Collaborative learning strategies promote active learning, critical thinking, and problem-solving skills (Gokhale, 1995; Major, 2022). In this study, collaborative learning strategies include think-pair-share, small-group discussion, role-playing, and jigsaw classroom. These activities were conducted as part of the student's learning experience. It allows students to learn through active involvement and cognitive tasks. Students are given opportunities to explore their learning potential to enhance learning.

Use of appropriate computer applications. The course guide also consists of laboratory exercises designed to promote the application and mastery of the concepts learned during the lesson proper. Laboratory activities and exercises are developed to provide students with learning experiences that will develop their laboratory skills and appreciation of the application of concepts learned in the real world. Laboratory activities developed are purely applications of MATLAB and MS Excel. These are computer software used in mathematical analysis. The teacher or the students may carry out laboratory activities to explore the world of mathematics, learn, discover, and develop an interest in the subject (Maheshwari, 2018). These activities and lessons make math interesting and effective by providing a proper context for application (Nichals, 2016). It is clearly reflected in the laboratory activities that students perform independent learning.

Figure 2 shows the varied student-centered and collaborative learning strategies employed.

Fig -2: Student-centered and collaborative learning strategies
(a. Gamification; b. Students' presentations; c. Think-Pair-Share; d. Small-group discussion and brainstorming; e. role-playing; f. Jigsaw classroom)

Table 1 summarizes the features of the resource-based course guide. The preceding discussions put stress on the utilization of a resource-based course guide manifesting its different features that could promote active learning and increase students' achievement.

Table **1.** Features of the resource-based course guide

Lesson No.	Topic	Features			
		Use of varied learning resources	**Use of student-centered strategies**	**Use of collaborative learning strategies**	**Use of appropriate computer applications**
II	Complex Numbers and their Operations	• Video 1: Complex Number-Why We Need Them • Lecture • MATLAB Guide for Complex Numbers • Activity Sheet	• Recitation • Seatwork • Gamification: Complex Numbers Bingo • Assignment		• Laboratory Activity 1
II	Polar Forms of Complex Numbers	• Powerpoint • Video 2: Teacher-made video lecture • Lecture • Video 3: De Moivre's Theorem Advance Lessons	• Recitation • Seatwork • Assignment	• Think-Pair-Share • Group Quiz	
III	De Moivre's Theorem	• Lecture	• Find my Product Activity • Recitation		• MATLAB Exercise 1

			• Quiz • Assignment		
IV	Exponential Forms of Complex Numbers	• Video 4: Exponential Form of a Complex Number • Lecture	• Recitation • Quiz • Assignment: Challenge problems	• Rec-Exp/Exp-Rec Conversion	• MATLAB Exercise 2
V	Laplace Transforms	• Video 5: Introduction to Laplace Transforms • Video 6: Teacher-made video lecture on Laplace Transform using Laplace integral • Lecture	• Recitation • Quiz • Assignment: Challenge problems	• Group Activity	• MATLAB Exercise 3
VI	Inverse Laplace Transforms	• Powerpoint • Lecture • Activity Sheet	• Recitation • Seatwork • Quiz • Assignment	• Think-Pair-Share	• MATLAB Exercise 4 • Laboratory Acti2
VII	Laplace Transforms Solutions to Linear Differential Equations	• Lecture	• Reporting • Quiz • Assignment	• Role-Playing • Poster Making	• MATLAB Exercise 5
VIII	Sequences and Series	• Activity Sheet • Lecture • Video 7: Advance Lessons on Convergence and Divergence	• Exploratory Activity • Recitation • Quiz • Assignment	• Exploratory Activity	
IX	Tests for Convergenc e and Divergence	• Jigsaw Classroom Activity Guide • Lecture • Laboratory Activity Sheets	• Recitation • Quiz • Assignment	• Jigsaw Classroom	• Laboratory Activity 3

3.2 Evaluation of the Resource-Based Course Guide by Jurors

The developed course guide was designed to guide instructors in their instructional delivery. It was made to be used as a ready reference for instructors to have innovative teaching-learning experiences for students. As instructional material, it is important that this should be evaluated by experts in the field. This is to ensure that the developed IM is valid and acceptable in the various aspects of IM development. The developed material as a course guide was evaluated based on the responses of the jurors to the criteria specified in the Course Guide Evaluation Instrument (CGEI). The material was evaluated in terms of its alignment, content, pedagogical component, and technical aspects (Table 2).

Table **2**. Summary of the evaluation

Indicators	Weighted Mean	Interpretation
Alignment	3.68	Very Satisfactory
Contents	3.69	Very Satisfactory
Pedagogical components	3.75	Very Satisfactory
Technical aspects	3.72	Very Satisfactory
Overall	**3.71**	**Very Satisfactory**

Along alignment, developed instructional material possessed a good alignment when it came to standards, content, assessment, and teaching strategies for its learning objectives. The material aligns with the engineering curriculum and standards. The material is found to be a useful resource material in preparing students to meet the requirements of the CHED standards. The developed material gives importance to the activities wherein the target performance standards of the students are anchored on addressing their struggles or needs.

In line with the contents, the developed material is found to be suitable for the students' level of development. In the paper on the development of IMs, Oden (2022) highlighted that one factor in the success of skill and knowledge acquisition in an instructional situation depends on the suitability of the IM. Therefore, teachers must seek materials addressing students' learning needs (Bugler et al., 2017). Also, IM's relevance to the lesson's objective is also a consideration in IM utilization to better the learner's performance (Oden, 2022). The developed IM included various activities that promote critical thinking, creativity, learning by doing, inquiry, problem-solving, etc. Also, along with the enhancement of desirable values and traits, the developed IM was found to be very satisfactory among the jurors. This result was supported by a study that explains that instructional materials should maximize learning potential by encouraging intellectual, aesthetic, and emotional involvement (Muñoz, 2010). Through the various activities incorporated in the instructional material, deeper learning will be facilitated, stimulating the development of the student's knowledge, skills, and values.

For the pedagogical components, the developed instructional material achieved its defined purpose. It is seen that the developed IM was designed to incorporate all the required contents to achieve the objectives set and assess the students' learning. The material was found to be enjoyable, stimulating, challenging, and engaging. This result implies that the various teaching strategies employed in the different topics are relevant to the teaching-learning process. Effective teaching strategies and methods are cues for improved learning (Jalbani, 2014). Also, the result was supported by a study that there is a positive impact of effective teaching strategies on producing good and fast learning outcomes (Raba, 2017). The development of the material focused on the inclusion of varied teaching strategies, which aimed to expose the students to different learning experiences to maximize learning. This agreed with a study that concluded that certain teaching methods are necessary in order to offer the participants aid and guidance on learning those strategies, promote the individual's already established learning strategies, and their creation of new knowledge (Wegner et al., 2013)

Then, the technical aspects, it can be seen that the developed IM considered the size of the letters, spaces between the letters and words, font use, and printing quality. Properly designed instructional material affects the performance of students. It is found in various studies that perceptual features, such as font size, type, and contrast, demonstrated a basis for self-judgments about memory, decision-making, and reasoning (Rodes & Castel, 2008; Alter & Oppenheimer, 2009; Weissgerber & Reinhard, n.d.). Specifically, perceptually clear materials are judged to be better learned than perceptually degraded materials. It was also seen through the result of the rating that the material is attractive and pleasing to look at, is simple, there is an adequate illustration in relation to text and harmonious blending of elements. This supported the findings that it is the responsibility of the designer to ensure that illustrations and visuals are in accordance with course objectives (Rashid et al., 2014). Also, the design of instructional materials is a potential contributor to academic success (Seeletso, 2015).

Generally, the Resource-Based Course Guide in Teaching Advanced Engineering Mathematics was very satisfactory, along with the various aspects as perceived by the jurors. The study's results support the claims that developed instructional materials were appropriate for use in the classroom (Dio, 2017; Tabal, 2015; Terano, 2015a; Terano, 2015b; Terano, 2018). These results may be attributed to resource-based learning as the foundation of the instructional strategies used in the lessons.

3.3 Effectiveness of the Resource-Based Course Guide in Improving the Achievement of Students in Advanced Engineering Mathematics

Achievement is the totality of all the students' acquired knowledge, skills, and attitudes as a result of the learning experiences. This achievement of students can be determined by various factors such as learning resources, strategies used by the instructor, the capacity of the learners, and many others.

To affect learning, various teaching techniques are employed. The ongoing adjustment of an organism's behavior depending on its experiences is known as learning (Drew, 2002). Learning therefore involves the modification of behavior brought on by environmental and developmental factors. Additionally, events both within and outside of schools can be used to assist learning (Igbo, 2012). It is believed that learning occurs inside in students' brains as a result of exposure to diverse stimuli and other circumstances.

Using pre-experimental design, a group of second-year electronics engineering students from Camarines Sur Polytechnic Colleges evaluated the effectiveness of the resource-based course guide. This was done to evaluate how well the developed material worked. Before using the content in any of the lessons, a pretest was given. A post-test, which focused on conceptual understanding and thinking skills, was administered after the students had utilized and been exposed to the generated material to see if there was a significant change between their pretest and post-test percentage scores. Table 3 presents quantitative information from the achievement test that was given both before and after the experiment.

Table 3. Results of the achievement test administered before and after the experiment

Topics	No. of Items	Score	Pretest (n=36)		Posttest (n=36)		t-value
			Mean	PL	Mean	PL	
1. Complex Numbers and its Operations	3	5	2.19	44%	4.25	85%	8.82*
2. Polar Forms of Complex Numbers	3	5	2.19	44%	4.19	84%	9.22*
3. De Moivre’s Theorem	3	5	2.00	40%	4.00	80%	7.10*
4. Exponential Forms of Complex Number	3	5	1.75	35%	4.08	82%	9.41*
5. Laplace Transforms	4	6	1.44	24%	4.86	81%	15.02*
6. Inverse Laplace Transforms	3	5	1.22	24%	4.03	81%	11.64*
7. Laplace Transforms Solution to Linear Differential Equations	3	5	1.28	26%	3.89	78%	9.42*
8. Sequences and Series	5	7	1.61	23%	5.67	81%	16.24*
9. Tests for Convergence and Divergence	5	9	1.44	16%	6.86	76%	21.88*
Over-all	**32**	**52**	**15.14**	**29% *(BC)***	**41.83**	**80% *(AC)***	**29.36***

* significant at 0.05 level of significance
BC-Beginning; AC-Approaching

Using the formula for ungrouped data, the pretest result of the achievement test is 15.14, which indicates a low-level achievement and heterogeneous grouping of the class, respectively. During the pretest, it was found that the proficiency level (PL) of 29% indicates that the students are at the beginning proficiency.

After the intervention, it can be noted that the result is 41.83, which indicated a significant increase in the mean. The t-value of 29.36 is greater than the tabular value of 1.994 at a 0.05 level of significance. The achievement means from 15.14 to 41.83 indicated an effect of an increase in the mean results of students’ achievements. This showed that the intervention caused the difference in the mean of the experimental class. It implies that the teaching-learning methods suggested in the developed material had positively affected the students' achievement. It is supported by a study that highlighted that the results of students’ achievement are laid on the teachers’ effective teaching strategies and methods for learning improvement (Jalbani, 2014). The PL (80%) of students during the posttest indicates that students are on approaching proficiency in the lessons.

Resource-based learning is the foundation of the course guide and had caused a greater difference in the student acquisition of knowledge. Resources given to students in their learning experiences allowed them to choose their own learning path while providing support structures as they construct their knowledge (Esch & Zähner, 2000). With the students’ exposure to various learning experiences, they gained the necessary knowledge, skills, and values that cause achievement in their performance.

Achievement along Multiple-choice Questions. The part I of the test are the multiple-choice items, and the results are given in Table 4. The t-value of 18.71 is greater than the tabular value of 1.994 at a 0.05 level of significance. This indicates that the intervention had caused the difference in the mean of the experimental class.

It was further reflected in the table that the students had gained achievement in all topics in Advanced Engineering Mathematics with positive mean differences. Data reveals that before the implementation, the students are in the Beginning Competence level having an overall mean score of 7.11 out of 22 items, with a proficiency level of 32%. It should be noted that after the implementation of the intervention, there was a significant increase in their mean scores. During the posttest, the students obtained the highest proficiency level on the topic, Polar forms of Complex numbers (85%), while the lowest proficiency level was on Tests for Convergence and Divergence (77%).

The students' low mastery on the tests for convergence and divergence was due to the fact that the question is about analyzing series and identifying first what specific test will be used. Moreover, since questions are on the last part of the test, students opted to answer first the easy questions that do not require computations. To summarize, the overall mean score of the students in the posttest is 17.86, with a proficiency level of 81%, which implies that the students are on approaching proficient in dealing with Advanced Engineering Mathematics concepts.

Table **4.** Result of the multiple-choice questions administered to the experimental class before and after the experiment

Topics	**No. of Items**	**Pretest (n=36)**		**Posttest (n=36)**		**t-value**
		Mean	**PL**	**Mean**	**PL**	
1. Complex Numbers and its Operations	2	1.11	56%	1.67	83%	3.76*
2. Polar Forms of Complex Numbers	2	1.14	57%	1.69	85%	4.21*
3. De Moivre's Theorem	2	1.00	50%	1.64	82%	4.26*
4. Exponential Forms of Complex Numbers	2	0.83	42%	1.67	83%	6.17*
5. Laplace Transforms	3	0.69	23%	2.47	82%	12.72*
6. Inverse Laplace Transforms	2	0.56	28%	1.64	82%	8.35*
7. Laplace Transforms Solution to Linear Differential Equations	2	0.56	28%	1.58	79%	6.94*
8. Sequences and Series	4	0.72	18%	3.19	80%	14.45*
9. Tests for Convergence and Divergence	3	0.50	17%	2.31	77%	11.58*
Over-all	**22**	**7.11**	**32% *(BC)***	**17.86**	**81% *(AC)***	**18.71***

* significant at 0.05 level of significance
BC-Beginning; AC-Approaching

The results showed that the learning experiences provided to the students as a result of using the resource-based course guide in teaching Advanced Engineering Mathematics had caused a positive impact along the multiple-choice questions. This finding was supported by a study that highlighted that resource-based learning is a knowledge-centered environment focusing on developing knowledge of the field or discipline and of strategies to develop expertise (Greenhow et al., 2006). The freedom to explore resources in a resource-based learning environment has given the learners a chance to explore their learning potential. As also presented in a study, a resource-based learning environment has a positive impact on student learning (Lee & Min Yu, 2004).

The foregoing results of the multiple-choice test implied that the basic cognitive skills involving knowledge acquisition and understanding of different facts, ideas, concepts, and theories in Advanced Engineering Mathematics were possible as a result of the implementation of the instructional strategy described in the lesson of the developed Resource-Based Course Guide. The learning modalities helped students develop understanding of the topics. The findings supported the juror's evaluation of the course guide, indicating that it is very satisfactory, which further implies that the developed material was considered valid and to be an effective material in enhancing student achievement in advanced engineering mathematics.

Achievement along Open-Ended Questions. The traditional educational structure placed a strong emphasis on memorization and the capacity to repeat material. Problem-solving was limited to the sciences and math. The focus of education nowadays is on giving students the knowledge and abilities they need to succeed in the world both inside and outside of the classroom. Simply being able to comprehend why things are the way they are and being aware of alternative outcomes is considered to be a critical thinking skill (Kasten, 2017).

For students, critical thinking is crucial because it teaches them how to think about any subject or problem they encounter so they can successfully handle it (Schneider, 2002). The student's chances of succeeding are significantly reduced by the lack of critical thinking techniques used in the classroom (Irfaner, 2006). Thus, it is apparent that teachers must include activities that promote thinking skills development in their instructional strategies. The resource-based course guide, for instance, developed by this study suggested instructional strategies and activities that can help conceptual and thinking skills development. The freedom to explore the variety of resources given to students allowed them to independently process the information to produce required outputs and accomplish learning tasks, which is a practice that can promote the development of thinking skills and creativity. The guide questions given after a laboratory or learning activity encourages them to think critically about the answer and apply it to certain situations. The brainstorming and small group discussions allowed learners to think better and thus develop high-order thinking skills. The video presentation given for selected topics required them to comprehend and associate events and situations in the video with their daily experiences. Being able to comprehend and form associations between materials and events can develop thinking skills (Ramirez, 2016).

To determine if the course guide can effectively improve student's achievement in terms of the thinking skills, open-ended questions were included in the achievement test administered to the students in the experimental class. Table 5 shows the results of the open-ended questions administered to the students. As seen in the table, the mean of the students in the test was 8.03, and it was increased to 23.97 after the intervention. The t-value of 31.06 is greater than the tabular value of 1.994 at a 0.05 level of significance. This indicates that the intervention had caused the difference in the mean of the experimental class. Another significant inference that may be deduced from the data in the table was the homogeneity of the mean scores. There were commonalities in the developed thinking skills of the students as reflected in the smaller range observed between the mean scores in the post-test for the different thinking skills tested. The positive difference noted between the pretest and posttest mean scores indicated a favorable achievement gain in the students' thinking skills after the intervention.

Table **5**. Results of the open-ended questions administered to the experimental class before and after the experiment

Topics	**No. of Items**	**Score**	**Pretest (n=36)**		**Posttest (n=36)**		**t-value**
			Mean	**PL**	**Mean**	**PL**	
1. Complex Numbers and its Operations	1	3	1.08	36%	2.58	86%	10.54*
2. Polar Forms of Complex Numbers	1	3	1.06	35%	2.50	83%	10.72*
3. De Moivre's Theorem	1	3	1.00	33%	2.36	79%	8.02*
4. Exponential Forms of Complex Numbers	1	3	0.92	31%	2.42	81%	10.98*
5. Laplace Transforms	1	3	0.75	25%	2.39	80%	12.05*
6. Inverse Laplace Transforms	1	3	0.67	22%	2.39	80%	11.86*
7. Laplace Transforms Solution to Linear Differential Equations	1	3	0.72	24%	2.31	77%	10.12*
8. Sequences and Series	1	3	0.89	30%	2.47	82%	10.52*
9. Tests for Convergence and Divergence	2	6	0.94 (0.47-ave)	16%	4.56 (2.28-ave)	76%	20.58*
Over-all	**10**	**30**	**8.03**	**27% *(BC)***	**23.97**	**80% *(AC)***	**31.06***

* significant at 0.05 level of significance
BC-Beginning; AC-Approaching

The students have low mastery of the topic on tests for convergence and divergence tests with an average score of 2.28. This was because the questions are about analyzing series, identifying first what specific test will be used, and explaining the concept behind the conclusion of whether the series is convergent or divergent. Moreover, the topic of tests for convergence and divergence is composed of six (6) different tests, which gives the students a hard time identifying what among the six tests will be used. To summarize, the overall mean score of the students in the posttest is 23.97, with a proficiency level of 80%, which implies that the students are on approaching proficient in dealing with Advanced Engineering Mathematics concepts.

The noted development of thinking skills based on the scores in part II of the achievement test is supported by the students' answers to the open-ended questions given to further measure thinking skills and reasoning of the learners. The questions were made to test students' abilities in principle formation, comprehension, problem-solving, and decision-making. Their ability to cognitively process information was a clear manifestation of the development of thinking skills.

4. CONCLUSIONS

Learning materials are key aspects in the delivery of instruction to students. Various learning materials are available. The use of these materials varies depending on the availability of the resources and group of students based on their capabilities and capacities to learn. Resource-based course guide is an instructional material that guides a teacher in the delivery of instruction. It is anchored on a resource-based learning approach that utilizes varied pedagogical components for maximum learning based on available resources. It advocates active and collaborative learning that is guided by the constructivist theory of learning.

Considering the importance of resource-based course guides as a learning and teaching guide in advanced engineering mathematics, professors need to innovate further other teaching strategies and modes of delivery that will enhance the knowledge, skills, and competencies of the students. They may further enhance the material in terms of its alignment, contents, pedagogical components, and technical aspects by incorporating other teaching and learning strategies and assessment methods based on the current needs and capacities of the students. Likewise, may design various developmental activities to further strengthen the achievement of students.

5. REFERENCES

Abolade, S. (2001). *An Introduction to Micro Teaching.* Nigeria: Indemake Publicity.

Alter, A. L., & Oppenheimer, D. M. (2009). Uniting the Tribes of Fluency to Form a Metacognitive Nation. *Pers. Soc. Psychol. Rev, 13*, 219-235.

Babbie, E. (2010). *The Practice of Social Research, 12th ed.* Belmont, CA: Wadsworth Cengage.

Bugler, D., Marple, S., Burr, E., Chen-Gaddini, M., & Finkelstein, N. (2017). *How teachers judge the quality of instructional materials.* CA: WestEd.

CDIO Standards 2.0. (n.d.). Retrieved from CDIO: http://www.cdio.org/implementing-cdio/standards/12-cdio-standards#standard5

Cranch, E. T. (1986). *Engineering Undergraduate Education.* Washington: National Academy Press.

Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2007). *Rethinking Engineering Education: The CDIO Approach.* New York: Springer.

DepEd. (2009). *Guidelines and Processes for LRMDS Assessment and Evaluation.* Department of Education.

DepEd. (2010). Discussion Paper on the Enhanced K+12 Basic Education Program. *DepEd Discussion Paper*.

Dio, R. (2017). Number Theory Work Text for Teacher Education Program. *The Normal Lights, 11(2)*, 143-179.

Drew, W. (2002). *Psychology, Brain, Behavior and Culture, 3rd Ed.* New York, NY: John Wiley.

Education, N. D. (2021). *Instructional Material Evaluation Rubric-CTE.* Retrieved from https://doe.nv.gov/uploadedFiles/ndedoenvgov/content/Standards_Instructional_Support/Instructional_Materials/evalurubric.pdf

Esch, E., & Zähner, C. (2000). The Contribution of Information and Communication Technology (ICT) to Language Learning Environments or the Mystery of the Secret Agent. *ReCALL, 12(1)*, 5-18.

Gokhale, A. A. (1995). Collaborative Learning Enhances Critical Thinking. *Journal of Technology Education, 7*(1), 22-30.

Greenhow, C., Dexter, S., & Riedel, E. (2006). Methods for Evaluating Online, Resource-based Learning Environments for Teachers. *Journal of Computing in Teacher Education, 23(1)*, 21-28.

Hill, J. R., & Hannafin, M. J. (2001). Teaching and learning in digital environments: The resurgence of resource-based learning. *Educational Technology Research and Development, 49(3)*, 37-52.

Honey, M., Pearson, G., & Schweingruber, H. (2014). *STEM Integration in K-12 Education: Status, Prospects, and Agenda for Research.* Washington, DC., USA: The National Academies Press.

Ibe, O. (2012). *Science Education in the Philippines.* Retrieved from http://www.rmaf.org.ph/madc/archive/files/up_cids_chro nicle_a9ac85e1df.pdf

Igbo, J. (2012). Creating Positive Learning Environment. *Journal of Science, Technology, Mathematics and Education, 8(2)*, 238-250.

Irfaner, S. (2006). Enhancing Thinking Skills in the Classroom. *Humanity and Social Sciences Journal, 1(1)*, 28-36.

Jalbani, L. N. (2014). *The Impact of Effective Teaching Strategies on the Student's Academic Performance and Learning Outcome.* Germany: GRIN Verlag.

Kasten, G. R. (2017, May 18). *Overcoming Obstacles to Critical Thinking.* Retrieved from Edutopia: https://www.edutopia.org/blog/critical-thinking-necessary-skill-g-randy-kasten

Kong, S. C., & So, W. M. (2008). A study of building a resource-based learning environment with the inquiry learning approach: Knowledge of family trees. *Computers & Education, 50(1)*, 37-60.

Lee, J., & Min Yu, B. (2004). A Learning Process in Resource-Based Well-Structured Instruction in Web-based Distance Learning environment. *ERIC Clearinghouse*, 527-533.

Maheshwari, V. (2018, November 30). *Mathematics Laboratory and Lab Method-Activity Oriented Pedagogy in Mathematics Learning*. Retrieved from Dr. V.K. Maheshwari, Ph.D: www.vkmaheshwari.com/WP/?p=2651

Major, C. (2022). Collaborative learning: A tried and true active learning method for the college classroom. *New Directions for Teaching and Learning*(170), 101-108.

Melsa, J. (2007). Transforming Engineering Education through Educational Scholarship. *Journal of Engineering Education, 96(3)*, 171-172.

Muijs, D. (2010). *Doing Quantitative Research in Education with SPSS. 2nd edition.* London: SAGE Publications.

Muñoz, J. (2010). Instructional materials: a platform to enhance cognitive skills and writing development. *Colombian Applied Linguistics Journal, 12*(1), 27-53.

Nichals. (2016, November 24). *The Benefits of Setting up a Math Lab in your School*. Retrieved from Nichal's Blog: http://www.nichalsworld.com/blog/benefits-setting-math-lab-school/

Oden, C. (2022). *Effects of instructional materials enhance the teaching/learning process by exhibiting information necessary to acquire knowledge and skills*. Retrieved from ProjectTopics: https://www.projecttopics.org/effects-instructional-materials-enhance-teaching-learning-process.html

Olaniyan, D., & Okemakinde, T. (2008). Human Capital Theory: Implications for Educational Development. *European Journal of Scientific Research, 24(2)*, 157-162.

Pearson, G., & Young, A. (2002). *Technically Speaking: Why all Americans Need to Know More About Technology.* Washington, DC: National Academies Press.

Raba, A. (2017). The Impact of Effective Teaching Strategies on Producing Fast and Good Learning Outcomes. *International Journal of Research - Granthaalayah, 5(1)*, 43-59.

Radu, M., Schnakovszky, C., Herghelegiu, E., Ciubotariu, V., & Cristea, I. (2020). The Impact of the COVID-19 Pandemic on the Quality of Educational Process: A Student Survey. *International Journal of Environmental Research and Public Health, 17*(21), 7770.

Ramirez, R. I. (2016). Resource-based course guide in teaching general inorganic chemistry integrated with environmental concepts. *International Journal of Chemical Studies, 4(4)*, 182-189.

Rashid, M., Mahmood, N., Khokhar, M. A., & Rashid, N. (2014). Role of designer in development of process of material of distance education. *Bulletin of Education and Research, 36*(2), 57-68.

Rodes, M. G., & Castel, A. D. (2008). Memory Predictions are Influenced by Perceptual Information: Evidence for Metacognitive Illusions. *J. Exp. Psychol. Gen, 137*, 615-625.

Ryan, S., Scott, B., Freeman, H., & Patel, D. (2013). *The Virtual University: The Internet and Resource-based Learning.* London: Routledge.

Schneider, V. (2002). *Critical Thinking in the Elementary Classroom: Problems and Solutions.* Retrieved from Educators Publishing Service: https://eps.schoolspecialty.com/downloads/articles/critical_thinking-schneider.pdf

Seeletso, M. K. (2015). *The design and development of instructional materials as a potential contributor to academic success of secondary school open and distance learners in Botswana.* Retrieved March 2021, from UPSpace Institutional Repository: https://repository.up.ac.za/handle/2263/52968

Tabal, K. (2015). Acceptability of PIC16F877A-based Microcontroller Training Unit and Laboratory Manual as a Supplemental Learning Material for Microprocessor Systems. *Asia Pacific Journal of Education, Arts and Sciences, 2(4)*, 66-70.

Terano, H. J. R. (2015a). Development and Acceptability of the Simplified Text with Workbook in Differential Equations as an Instructional Materials for Engineering. *Asia Pacific Journal of Multidisciplinary Research, 3(4)*, 89-94.

Terano, H. J. R. (2015b). Development and Acceptability of the Simplified Text in Differential Calculus for Engineering. *Journal of Multidisciplinary Studies, 4(2)*, 106-126.

Terano, H. J. R (2018). Development and Effectiveness of a Textbook on Advanced Mathematics for Engineering Programs. *International Journal of Educational Sciences, 23(1-3)*, 7-13.

Terano, H. J. R. (2019). Development of Integrated Curricula for the Master of Engineering Programs Using the CDIO Framework. *International Journal of Engineering Pedagogy, 9*(3), 44-55.

Tran, N., & Nathan, M. (2010). The Effects of Pre-Engineering Studies on Mathematics and Science Achievement for High School Students. *International Journal of Engineering Education*, *26(5)*, 1049-1060.

Wang, J., & Morgan, G. (2010). Pre-Experimental Designs. In N. Salkind, *Encyclopedia of Research Design.* SAGE Publications, Inc.

Weissgerber, S. C., & Reinhard, M. A. (n.d.). Is Disfluency Desirable for Learning? *Learn. Instr., 49*, 199-217.

Wegner, C., Minnaert, L., & Strehlke, F. (2013). The Importance of Learning Strategies and How the Project 'Kolumbus-Kids' Promotes them Successfully. *European Journal of Science and Mathematics Education, 1(3)*, 137-143.

Yuson, D. M. (2018). *Instructional Materials Evaluation Tool.* Retrieved from Scribd: https://www.scribd.com/document/368199812/Instructional-Materials- Evaluation-Tool-Final-1?utm_medium=cpc&utm_source=google_pmax&utm_campaign=3Q_Google_P erformance-Max_RoW&utm_term=&utm_device=c&gclid=CjwKCAjwitShBhA6EiwAq3Rq AyabAK6tqiqm4cGWvIcJN1YM_Qmoxn_