



Development and Effectiveness of a Textbook on Advanced Mathematics for Engineering Programs

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ABSTRACT Advanced Engineering Mathematics is a course that introduces higher concepts of mathematics and its applications to engineering. A textbook was developed to supplement the teaching-learning processes. The study had utilized the ADDIE (Analysis, Design, Develop, Implement, and Evaluate) model in developing the instructional material. The acceptability of the contents, structure and format and assessment in the IM was determined using a validated evaluation instrument. The instrument together with the IM was distributed to 22 engineering professors from various academic institutions and 80 engineering students using expert-based method of obtaining evaluation. Thirty civil engineering students were the participants to test the effectiveness of the material. Results showed that the IM is highly acceptable, and is effective and found that there is a significant improvement in the students' performance in the pretest-posttest. The study is important in providing an effective IM for engineering students to improve their proficiency in advanced engineering mathematics.

INTRODUCTION

Education is an important aspect for everyone in succeeding life and future. It helps a lot in combating life challenges and difficulties. Knowledge, skills and values gained throughout the education period enables every individual to be confident in their respective lives.

Learning in the sense of cognitive improvement is a multi-faceted construct related to multiple educational and individual factors (Drigas and Karyotaki 2014). It has been an actively focused on the process of acquiring new objective knowledge in the subject (Sousa-Vieira et al. 2015). The concept of a learner-centered and not teacher-centered is the new vision of the whole educational system (Maceiras et al. 2013). One of these factors include teaching and learning materials of various forms. Instructional materials refer to the human and non-human materials and facilities, which can be used to ease, encourage, improved and promote teaching and learning activities.

Instructional materials are very vital in the teaching-learning processes. This is in a form of textbooks, reference text, the chalk and blackboard, computer aided presentations and other materials that are important and useful in the discussion and teaching. Instructional material is a prominent factor toward academic excellence. It is remarkable for the teacher to develop instructional material to guide the student in their aca-

demical performance (Quisumbing et al. 2017). Textbooks are materials containing all the topics that should be discussed in a particular course. These instructional materials should be curriculum based and substantial for the purpose of teaching and the learning of the students. To concretize and substantiate learning, it is important to provide adequate, appropriate and varied instructional materials (Tominez et al. 2013).

Instructional design models are useful in developing course materials for effective teaching-learning processes. Instructional designers use learning theories as a source for verifying strategies and as a foundation for intelligent selection of strategies (Ertmer and Newby 2013). According to Branch and Kopcha (2014), developing instructional materials require a systematic approach and a more defined model. There are variety of instructional development models. ADDIE model is an acronym for analyze, design, develop, implement, and evaluate (Aldoobie 2015). The phases of ADDIE represent the fundamental concepts of instructional development process ensuring that the design has to be student-centered, goal-oriented with meaningful performance and outcomes that can be validly measured (Reiser and Dempsey 2012).

Advanced Engineering Mathematics is a higher course in engineering mathematics. The course description for advanced engineering mathematics for civil and mechanical engineer-

ing is stated in CMO 29, s. 2007 and CMO 9, s. 2008.

One of the significant challenges in teaching advanced engineering mathematics is on how to deliver to the students the concepts of the subject since majority of the topics focused on higher topics in mathematics that needs prior knowledge of the basic engineering mathematics. Also, there is a need to revisit the arrangement of the topics taking into considerations the pre-requisite topics. Several developments and evaluation study of instructional materials were conducted (Terano 2015; Tabal 2015; Dio 2017; Magulod 2017). Such studies are useful for other professors who intended to design their instructional materials related to their fields of specializations.

Objectives

This study focused on the development and effectiveness of a textbook in advanced engineering mathematics. Specifically, this study sought to address the following objectives, namely, 1) to design a textbook in terms of contents, structure and format, and assessments; 2) to determine the acceptability of the material in terms of contents, structure and format, and assessments; and 3) to test the effectiveness of the proposed textbook.

METHODOLOGY

This research employed a descriptive-development research design in the whole processes of the research. The study considered two ma-

ior phases, namely, the development and evaluation phases. The development phase included several stages such as planning, designing and development of the proposed textbook. The evaluation phase included the validation of the contents, structure and format, and assessment, and evaluation on the effectiveness of the material.

Development Phase

The planning phase of this study included preliminary activities in which the researcher considered the analysis of the present requirements for the course based on the course description and outlines of the Philippine Commission on Higher Education (CHED). The design of the material considered the contents and structure and format. Along the contents, the researcher considered the minimum requirements for the course in accordance with the CHED. Table 1 shows the outline for the course as prescribed in the CHED CMOs.

Along the structure and format, the researcher devised his own style on how he can make the material based on the needs of the students and on how this material can capture the interests of the students. This is to take note that according to Quisumbing et al. (2017), it is important for a teacher to develop instructional material to guide the student in their academic performance.

Evaluation Phase

After the completion of the textbook, twenty-two (22) engineering professors from the var-

Table 1: Course requirements

<i>Course title: Advanced Engineering Mathematics for CE</i>	<i>Course title: Advanced Engineering Mathematics for ME</i>
Course description: A study of selected topics in mathematics and their applications in advanced courses in engineering and other allied sciences. It covers the study of Complex numbers, Laplace and Inverse Laplace Transforms, Power Series, Matrices and Determinants, Vector Analysis and Numerical Methods.	Course description: A study of selected topics in mathematics and their applications in advanced courses in engineering and other allied sciences. It covers the study of Complex Numbers, Laplace and Inverse Laplace Transforms, Power series, Fourier series, Matrices and Determinants, Vector Analysis and Numerical Methods.
<i>Course Outline:</i>	<i>Course Outline:</i>
<ol style="list-style-type: none"> 1. Complex Numbers 2. Laplace and Inverse Laplace Transforms 3. Power Series 4. Fourier Series 5. Vector Analysis 6. Numerical Methods 	<ol style="list-style-type: none"> 1. Complex Numbers 2. Laplace and Inverse Laplace Transforms 3. Power Series 4. Fourier Series 5. Vector Analysis 6. Numerical Methods

ious universities and colleges in the Bicol region evaluated the material as expert evaluators. They were five (5) professors from the Camarines Sur Polytechnic Colleges (CSPC), three (3) professors from the Bicol University College of Engineering (BUCENG, Legazpi City), three (3) professors from the Bicol University Polangui Campus (BUPC), three (3) professors from the University of Northeastern Philippines (UNEP), two (2) professors from the University of Saint Anthony (USANT), three (3) professors from the Sorsogon State College (SSC) and three (3) professors from the Camarines Norte State College (CNSC). Data were collected in January 2017.

Each of them received a sample copy and were asked to evaluate the acceptability of the contents, structure and format and assessment of the material. Also, another group of evaluators on the acceptability of the material were the 80 engineering students in 2 universities, namely, Camarines Sur Polytechnic Colleges and University of Northeastern Philippines who had used the material. Since they had used the material, they were able to answer evaluation forms given to them to evaluate the acceptability of the contents, structure and format and assessment of the material. Weighted mean was used in order to consolidate the results that was obtained based on the response of the evaluators. The computed mean ratings were evaluated according to the scale as shown in Table 2.

Table 2: Likert scale

<i>Scale</i>	<i>Verbal interpretation</i>
4.50 – 5.00	Highly acceptable
3.50 – 4.49	Very acceptable
2.50 – 3.49	Acceptable
1.50 – 2.49	Fairly acceptable
1.00 – 1.49	Not acceptable

Table 3: Contents of the book

<i>CHED requirements</i>	<i>The proposed textbook</i>
I. Complex Numbers	Chapter 1: Complex Numbers and Complex Variables
II. Laplace Transforms	Chapter 2: Laplace Transforms
III. Power Series	Chapter 3: Infinite Series
IV. Fourier Series	Chapter 4: Power Series
V. Matrices and Determinants	Chapter 5: Fourier Series
VI. Vector Analysis	Chapter 6: Matrices and Determinants
VIII. Numerical Methods	Chapter 7: Vector Analysis
	Chapter 8: Numerical Methods
	Chapter 9: Introduction to Partial Differential Equations

To test the effectiveness of the material, the researcher seek permission from the Dean of the College of Engineering of the Camarines Sur Polytechnic Colleges to allow the researcher to conduct experimental study to 30 engineering students as his participants in the study. The researcher conducted one-group pretest-posttest experimental research design in testing the effectiveness of the material as part of the validation process. t-test was used to determine if there is a difference between the results of the pretest and posttest.

RESULTS AND DISCUSSION

The development and evaluation of the textbook in advanced engineering mathematics were conducted to satisfy the objectives of this research, namely, the design, acceptability and the effectiveness of the textbook in advanced engineering mathematics.

The Design of the Material

The textbook in advanced engineering mathematics is composed of nine (9) chapters together with its discussions, sample problems and exercises. Table 3 shows the contents of the book against the content topics in accordance with the minimum requirements of the Commission on Higher Education (CHED) in the Philippines. Identifying the contents of instructional materials can be aided with sample syllabi or course website (Peterson 2003).

The design of the material was carefully made to enhance the interests of the students in the course. Each chapter has the format and sequence using English as the language. The order of presentation is as follows: (1) Chapter Number and Title which provides the order and name of the chapter respectively; (2) Chapter

Overview which provides an introduction and overview of the topics that were included in each chapter; (3) Chapter Outline which indicates the list of the topics that was covered by the chapter; (4) Learning Objectives which indicates the objectives or learning outcomes of the study after the completion of each chapter; (5) Lesson Number and Topic which indicates the order and the name of the topic in every chapter, respectively; (6) Discussions which is the presentation of the basic concepts, formulas, theories and insights of the lesson; (7) Sample Problems and Solutions which are carefully solved problems in every lesson/topic; and (8) Exercises which are the activities that will be done by the students after taking the lesson. According to Hartley (2013), the format and sequence of information have practical significance to clarify the structure of the text and help the readers gain access to the information.

Acceptability of the Material

The acceptability of the textbook was done by tabulating the data gathered on the evaluation of the textbook by a total of twenty-two professors and eighty engineering students. Table 4 shows that the acceptability of the textbook in terms of the contents are highly acceptable. Taking into considerations the indicators evaluated, the results confirmed that the general contents of the IM which include the topics, problems and exercises are aligned with the objectives of the lesson. The results imply that the contents could provide students the instructional strategies that would enhance their cognitive, psychomotor and affective domains of learning

Table 4: Acceptability of the contents

<i>Indicators</i>	<i>Students</i>		<i>Professors</i>		<i>Total</i>	
	<i>WM</i>	<i>SD</i>	<i>WM</i>	<i>SD</i>	<i>WM</i>	<i>VI</i>
1. Support of the objectives to the topics, problems and exercises	4.83	0.380	4.73	0.538	4.78	HA
2. Relevance of the problems and exercises on the topics	4.86	0.344	4.59	0.577	4.73	HA
3. Relevance of the problems and exercises on the objectives	4.93	0.263	4.91	0.287	4.92	HA
4. Suitability of the topics to the learning ability of the students	4.90	0.300	4.77	0.419	4.84	HA
5. Suitability of the discussions on the interests and needs of the students	4.88	0.331	4.82	0.386	4.85	HA
Total	4.88	0.038	4.76	0.118	4.82	HA

Legend: WM-Weighted Mean; SD-Standard Deviation; VI-Verbal Interpretation; HA-Highly Acceptable

since the objectives developed are based on Bloom's Taxonomy (Adams 2015). The contents are highly acceptable considering that during the designing of the IM, the CHED course outlines were used as a guide to ensure that the required standards and competencies are met. The results also imply that the contents are suitable to the learner's ability and needs. This result was supported by Reiser and Dempsey (2012), that suitability is attained when the contents are student-centered and goal oriented coupled with relevant activities.

Table 5 shows that the acceptability of the textbook in terms of the structure and format are highly acceptable. The results imply that the structure, format and presentation of the discussions are suitable to the level of student understanding. The findings also suggest that there is clarity in the discussions of the topic and presentation of concepts and theories. It is further assumed from the results that the sample problems and solutions that were developed are based on the objectives and are clearly illustrated for easy understanding of the topic. According to Hartley (2013), students have different needs and preferences in the learning preferences and the clarity of the discussion could help address such variation. Clarity in the text is mandatory and regarded as the most effective criterion for an effective instructional material (IM) (Gerson 2000).

Table 6 shows that the acceptability of the textbook in terms of the assessment are highly acceptable. The results confirmed that the exercises given are sufficient for the students to learn the concepts and theories in every topic in each chapter. According to Paas and Sweller (2014),

Table 5: Acceptability of the structure and format

Indicators	Students		Professors		Total	
	WM	SD	WM	SD	WM	VI
1. Simplicity of the structure	4.93	0.263	4.91	0.287	4.92	HA
2. Organized format	4.96	0.190	4.86	0.457	4.91	HA
3. Clear presentation of the discussions	4.90	0.300	4.77	0.419	4.84	HA
Total	4.93	0.030	4.85	0.071	4.89	HA

Legend: WM-Weighted Mean; SD-Standard Deviation; VI-Verbal Interpretation; HA-Highly Acceptable

Table 6: Acceptability of the assessment

Indicators	Students		Professors		Total	
	WM	SD	WM	SD	WM	VI
1. Sufficiency of the Exercise given	4.88	0.331	4.55	0.498	4.72	HA
2. Clearly stated problems	4.91	0.283	4.68	0.466	4.80	HA
3. Suitability of the exercises to the level of the learner	4.85	0.357	4.82	0.386	4.84	HA
Total	4.88	0.030	4.68	0.135	4.79	HA

Legend: WM-Weighted Mean; SD-Standard Deviation; VI-Verbal Interpretation; HA-Highly Acceptable

sufficient exercises avoids overloading the learner's cognitive capacity. The results also showed that the problems are clearly stated, and exercises are suitable for the level of the learner. Assessment must be parallel to and able to measure the learners' ability to perform what is described in the objectives (Dick et al. 2014). Problem sets will enhance the critical thinking of students. Terano (2015) stressed that, the focus on tertiary curriculum should not only be on the theoretical aspects but also on the skills which involve activities that will enhance the critical thinking of students.

Table 7 shows the summary of the perceived acceptability of the textbook along its contents, structure and format and assessment. As shown in the table, the various indicators as perceived by the professors and students, it is found that there is no significant difference on their perceptions on the acceptability of the textbook in

terms of the contents, structure and format, and assessment.

Generally, the developed material is highly acceptable in terms of its contents, structure and format and assessment. This only implies that the developed material is suitable for use in engineering programs. Results of the study support the claims of Dio (2017), Tabal (2015) and Terano (2015), that developed instructional materials were appropriate to be used in the classroom.

The developed material was highly acceptable based on the evaluations as discussed in the previous section. Some of the suggestions and recommendations of the evaluators were; (1) include an overview of each chapter, (2) provide separate page (one whole page) for the start of every chapter, and (3) include in every chapter page the list of topics/chapter outline. Based on these suggestions, the researcher had revised the material.

Table 7: Over-all results of the acceptability of the textbook in advanced engineering mathematics

Indicators	Weighted means		F-value	p-value
	Students	Professors		
Content	4.88	4.76	4.36	0.070*
Structure and Format	4.93	4.85	3.51	0.134*
Assessment	4.88	4.68	6.06	0.069*
Total	4.90	4.76	6.61	0.062*

Legend: *not significant at 0.05 level of significance

Effectiveness of the Textbook in Advanced Mathematics for Engineering

The effectiveness of the textbook was tested using the one-group pretest-posttest experimental design among the group of third-year civil engineering students in one state college in the Bicol region. This was conducted to determine the effectiveness of the developed textbook. Pretest was conducted before the actual utilization of every chapter of the material. Posttest was conducted after the utilization and exposure to the developed material to determine whether there is a significant difference in the pretest percentage scores and the posttest percentage scores of the students. Table 8 shows the mean performance of the civil engineering students during the pretest and posttest including the corresponding *t*-value for each topic.

As observed in Table 8, the students significantly improved during the posttests as compared to the pretests. The pretest results of the topics Complex Numbers and Complex Variables, Laplace Transforms and Matrices and Determinants showed that some of the students had already prior knowledge about these topics while the remaining topics showed that the students had no background at all. Generally, there is a significant improvement in their performance in the posttest as compared to their pretest results.

CONCLUSION

The design of the Textbook in Advanced Engineering Mathematics follows the minimum requirements for the course in accordance with the CHED CMOs of the Philippines. The design

of the material was carefully made to enhance teaching-learning processes in the course. Each chapter has the format and sequence using English as the language. The material is highly acceptable based on the evaluations of professors and students in terms of the contents, structure and format, and assessment. The material is effective based on the results of the pretests and posttests of the students. The material is suitable for use in engineering programs. The content of the material was revised based on the suggestions and recommendations of the evaluators.

RECOMMENDATIONS

The proposed material can be used in the various institutions of higher learning offering courses in advanced engineering mathematics. Further evaluation can be done to improve the content, structure and format and assessment of the material. Item analysis can be conducted to further improve the acceptability of the material in terms of the assessment. The professors and students in advanced engineering mathematics can use the material for an effective teaching and learning processes. Revisions on the content can be done in accordance with changes and updates in curriculum. This material can serve as input to other researchers in conducting similar studies.

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Table 8: Effectiveness of the textbook in improving the performance of the students

<i>Indicators</i>	<i>Mean performance (%)</i>		<i>t-value</i>
	<i>Pretest</i>	<i>Posttest</i>	
Complex Numbers and Complex Variables	55.83	88.33	10.50*
Laplace Transforms	12.67	83.83	52.74*
Infinite Series	0.83	86.00	74.92*
Power Series	0.00	84.33	70.73*
Fourier Series	0.00	83.83	71.86*
Matrices and Determinants	63.00	90.17	8.57*
Vector Analysis	1.33	88.83	63.78*
Numerical Methods	0.00	89.33	68.34*
Introduction to Partial Differential Equations	0.00	88.67	75.60*
Total	14.85	87.04	89.20*

*Significant at 0.05, $t_{\text{crit}} = 2.045$

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