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Development and Acceptability of the Simplified Text in Differential Calculus for Engineering

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Abstract

Differential Calculus is a course that introduces the concepts and theories of higher mathematics and their applications to engineering. A large majority of engineering students fail to attain proficiency in mathematics as the foundation course of engineering programs. One way to help students obtain skills and competency is to develop an effective instructional material (IM). In an attempt to provide the engineering students IM that can supplement their learning process, this study aimed to develop a Simplified Text in Differential Calculus for engineering and determine its acceptability. The study utilized the ADDIE (Analysis, Design, Develop, Implement, and Evaluate) model in developing the IM. The acceptability of the objectives, contents, presentation and style, and exercises in the IM was determined using a validated evaluation instrument. The instrument together with the IM was distributed to 22 engineering professors from the different academic institutions in the Bicol Region using the expert-based method of obtaining the evaluation. The weighted mean was the statistical tool used. Results showed that all text features are highly acceptable. The study is important in providing an effective IM for engineering students to improve their proficiency in higher mathematics.

Keywords: design, evaluation, learning, mathematics, model

Introduction

It is a great challenge in every educational institution on how to enhance the quality and standards of the engineering program. There have been issues that drive the advancement of engineering education in the United States in particular. These include a declining interest of students in engineering (Melsa, 2007), a decrease in national achievement in mathematics and sciences at pre-college levels (Tran & Nathan, 2010), and a lack of technological literacy (Pearson & Young, 2002). Hence, focusing on the education of pre-college population becomes an alternative to improve situations facing science, technology, engineering, and mathematics (STEMs) education (Honey, 2014).

In the Philippines, engineering education also has such concerns on how to improve the knowledge and skills of students. In K-12 program implementation, the present quality of education is reflected in the inadequate preparation of high school graduates for higher education because they lack the core competencies or emotional maturity (DepEd, 2010).

With the prevailing issues, Terano (2015) stressed that the educational curriculum at the tertiary level should focus both on theories and skills which involve activities that enhance the critical thinking. Differential Calculus is a higher engineering mathematics course that is taken mostly during the first semester of the second year. The course introduces the concepts and theories of higher mathematics and their applications to engineering. However, a large majority of engineering students fail to attain proficiency in higher mathematics subjects that serve as foundation courses of engineering programs (Terano, 2015).

One way to help students develop skills and competency is to design a course material for effective instruction (Morrison et al., 2010; McClure, 2006). Instructional materials are a prime concern in teaching (Terano, 2015). They are in the form of textbooks, reference text, the chalk and blackboard, computer-aided presentations and other materials necessary and useful in the learning process.

Learning theories and instructional design (ID) models are helpful in developing course materials for effective instruction. For instance, instructional designers may use the learning theories as a source for verifying strategies and as a foundation for intelligent selection of strategies (Ertmer & Newby, 2013). Behaviorism, cognitivism, and constructivism are three primary learning theories that provide the andragogical basis for understanding how students learn (Keesee, 2012).

Behaviorism only focuses on objectively observable behaviors and discounts mental activities of the mind while cognitivism focuses on the "brain" as it emphasizes intelligence as a special endowment for an individual to develop intellectually (Keesee, 2012). Constructivism, on the other hand, focuses on how learners construct the meaning from new and prior knowledge.

In addition to the primary learning theories, the adult learning theory, cognitive load theory, and multimedia theory are important theories that also affect the approach in designing instruction to accommodate the learners' characteristics and experience. Applying the adult learning theory when designing instruction, one should capitalize on the learner's experience (Merriam et al., 2012). The application of the cognitive load theory in ID lies on the limitation of the learner's working memory (Sweller et al., 1998). The multimedia theory has a similar goal with the cognitive load theory which is the use of evidence-based principles for ID that avoids overloading the learner's cognitive capacity (Paas & Sweller, 2014).

Developing instructional materials requires a systematic approach and a more defined model according to Branch and Kopcha (2014). There are a variety of ID models developed earlier (Gustafson & Branch, 1997) and all of these contain the core elements of ADDIE which is an acronym for analyze, design, develop, implement, and evaluate (Aldoobie, 2015). The phases of ADDIE represent the fundamental concepts of the ID process ensuring that the design has to be student-centered, goal-oriented with meaningful performance and outcomes that can be validly measured (Reiser & Dempsey, 2012).

The phases of the ADDIE model are related to and interact with each other (Aldoobie, 2015). In the analysis phase, the instructional designer analyzes the existing knowledge, skills, experience, and attitudes of the target learner and determines instructional goals as well as the learning environment. Beishuizen and Stoutjesdijk (1999) stated that the quality of learning material is enhanced if the students' learning styles are taken into account.

In the design phase, the designer identifies the learning objectives to outline contents and instructional strategies. The Bloom's Taxonomy is helpful in writing the learning objectives and classifying them based on complexity and specificity using the cognitive, psychomotor, and affective learning domains (Adams, 2015). The learners must be able to access and engage with the learning materials which match or accommodate their learning preferences (Jonassen & Wang, 1993). Hence, the designer would think of how the instruction can be effective in ways that able the learners to interact with the materials (Aldoobie, 2015).

In the development phase, the designer creates the instructional contents, a prototype, and assessment tools while the implementation phase is the actual delivery of IM in the settings for which it was designed (Aldoobie, 2015). The evaluation phase includes formative and summative evaluation (Dick et al., 2014).

Evaluation studies of the quality of IM to improve the instruction are few (Weiten et al., 1999; De Jong & Lentz, 1996; Hamilton, 1985; Weston et al., 1997; Baktash & Talebinejad, 2015). The book of Hartley (2013) offers guidelines for writing instructional text and explains the methods of evaluating its quality. Evaluation studies of the quality of Engineering textbooks, in particular, are carried out in other Asian countries like Japan, China, and Korean and are more focused on language barrier (Yan & Jie, 2014; Arimitsu et al., 2014). The recent development and evaluation study of IM for engineering was conducted by Terano (2015). Such study is useful for other instructors who intend to design their IM related to their field of specialization.

In an attempt to provide the engineering students quality instructional material (IM) that can supplement their learning process, this study aimed to develop a Simplified Text in Differential Calculus for engineering and determine its acceptability. The study is important in providing an effective IM for engineering students to improve their proficiency in higher mathematics.

Materials and Methods

This study is a descriptive developmental research. The ADDIE framework described by Aldoobie (2015) was used to design and develop the Simplified Text in Differential Calculus for Engineering. The acceptability of the objectives, contents, presentation and style, and exercises in the IM was determined using a validated evaluation instrument.

The development of the IM started with the planning and conceptualization of what to do to generate material for Differential Calculus useful for engineering programs. A review of related studies and literature served as the guide on what to develop based on student needs and the curriculum in the engineering education. The information was analyzed and used for designing the IM.

During the designing process, the objectives were formulated, and other references were examined to outline the contents. The other features in the IM designed were the presentation and style, and exercises. The topics included in the material followed the CHED (Commission on Higher Education) minimum requirements for Differential Calculus for engineering programs based on CHED Memorandum Order (CMO) No. 12, series of 2008 (CHED, 2008) as shown here.

CHED Course Outline for Differential Calculus

1. Functions
2. Continuity
3. Limits
4. The Derivative
5. The Slope
6. Rate of Change
7. The Chain Rule and General Power Rule
8. Implicit Differentiation
9. Higher-Order Derivatives
10. Polynomial Curves
11. Applications of the Derivatives: Optimization Problems
12. Applications of the Derivatives: Related Rates
13. The Differential
14. Derivatives of Trigonometric Functions
15. Derivatives of Inverse Trigonometric Functions
16. Derivatives of Logarithmic Functions
17. Derivatives of Hyperbolic Functions
18. Solution of Equations
19. Transcendental Curve Tracing
20. Parametric Equations
21. Partial Differentiation

During the development of the IM, a careful analysis of the contents based on the course outline was undertaken. The discussions were in the correct sequence with the outline and kept simple to suit the level of the learner's understanding. Encoding the contents of the material took a lot of time since it is necessary not to make any error especially in the equations. Grammar editing and checking of the right terms were done.

After developing the material, an evaluation instrument was formulated and validated to determine the acceptability of the material. The instrument was composed of four parts, namely: objectives, contents, presentations and style, and exercises. The instrument has a total of 14 indicators of acceptability. Three indicators were evaluated to determine if the objectives were acceptable and these are: 1) The cognitive, psychomotor and affective statements of the

objectives, 2) Simplicity and attainability, and 3) Suitability to the particular topic. Five indicators were evaluated to determine if the contents were acceptable. These indicators include 1) Support of the objectives to the topics, problems and exercises, 2) The relevance of the problems and exercises on the topics, 3) The relevance of the problems and exercises on the objectives, 4) Suitability of the topics to the learning ability of the students, and 5) Suitability of the discussions on the interests and needs of the students. Three indicators were assessed to determine if the presentation and style were acceptable and these are: 1) Terms used, 2) Language used, and 3) Clear presentation of the discussions. Three indicators were also evaluated to determine if the exercises were acceptable and these are: 1) Sufficiency of the exercises given, 2) Clearly stated problems, and 3) Suitability of the exercises to the level of the learner.

The evaluation instrument together with the IM was distributed to 22 engineering professors from the target academic institutions in the Bicol Region using the expert-based method of Schriver (1989, 1990, 1997) in determining the acceptability of the IM. The evaluators were composed of 10 professors from Camarines Sur Polytechnic Colleges (CSPC) in Nabua, Camarines Sur; four (4) professors from the Bicol University Polangui Campus (BUPC) in Polangui, Albay; five (5) professors from the University of Northeastern Philippines (UNEP), and three (3) professors from the University of Saint Anthony (USANT), both institutions are situated in Iriga City.

The five-point Likert scale was used to evaluate the level of acceptability of the material. The weighted mean was the descriptive statistics used to determine the acceptability. The following continuum was used to generate the interpretation of the evaluation: 4.20–5.00 (Highly acceptable); 3.40–4.19 (Somewhat acceptable); 2.60–3.39 (Moderately acceptable); 1.80–2.59 (Fairly acceptable); 1.00–1.79 (Not acceptable). The standard deviation (SD) was determined to calculate the coefficient of variation (CV) which was interpreted as the percentage of variability of the responses. The standard value is at most 10% which assures that the responses are comparable.

Results and Discussion

Eleven chapters compose the Simplified Text in Differential Calculus for Engineering. These chapters are presented as follows: (1) Functions, Limits and Continuity, (2) Derivatives, (3) Algebraic Functions, (4) Applications of Derivatives, (5) Trigonometric and Inverse Trigonometric Functions, (6) Exponential and Logarithmic Functions, (7) Hyperbolic and Inverse Hyperbolic Functions, (8) Parametric Equations, (9) Curvature, (10) Indeterminate Forms, and (11) Partial Differentiation. The CHED minimum requirement for Differential Calculus for engineering serves as the guide in outlining the contents of each chapter. The instructional outline provided by the CHED is an essential reference to analyze in developing the contents of the material. Peterson (2003) emphasized that identifying the contents of the material can be aided with sample syllabi or course website. Accordingly, instructors or designers when developing an IM have to examine standards and competencies to establish a foundation when determining what topics that student would need. Updated Policies, Standards and Guidelines (PSG) for the engineering program are accessible online in CHED website and can provide a workable template when preparing the contents of the material.

Each chapter follows the same format and sequence using English as the language. The order of presentation is as follows: (1) Chapter Number and Title which state the order and name of the chapter, respectively; (2) Learning Objectives which serve as the guide for the students on what to learn in a particular chapter; (3) Lesson Number and Topic which indicate the order and the name of the topics in every chapter, respectively; (4) Discussion which is the presentation of the basic concepts, formulas, theories and insights of the lesson; (5) Sample Problems and Solutions which are carefully and systematically solved problems in every lesson; and (6) Exercises, which are problems for every topic or subtopics in every chapter.

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 (Hartley, 2013). Readers tend to skim, search,

and re-read the text instead of only reading the material from beginning to end (Hartley, 2004). The devices that aid students navigate the text include titles, outlines, headings and subheadings, and numbering system. Moreover, these devices can help students recall what the text is all about. Concrete titles for example rather than those that are abstract may improve the recall, comprehension, and interest of undergraduate students (Sadoski et al., 2000).

In this simplified text, the learning objectives are designed to articulate the knowledge and skills that the students acquire by the end of the course. They are simple, attainable, and suitable to the topic. The learning objectives of the material were constructed using the Bloom's Taxonomy of the cognitive, affective, and psychomotor learning domains as emphasized by Adams (2015). The learning objectives are important in examining the quality of an IM. With the expert-based method of evaluating the quality of the instructional text, the concern lies on whether the material could meet the objectives as to the depth of the contents. Teacher, for example, may want to decide whether the IM is suitable for their students and the learning objectives can aid them in their judgment (Hartley, 2013). The effectiveness of IM depends on the manner and the degree to which they meet the needs of teachers and students (Idowu, 2010). From the reader-based perspective of determining the quality of an IM, a study showed that the learning objectives are among the text features that different groups of students rated useful (Marek et al., 1999). An earlier study also showed that the learning objectives are cues that direct the reader's attention (Schallert et al., 1988).

Lesson number is another feature in this simplified text used to clarify the structure of the IM and to organize topics in the text as Hartley (2013) also stressed. Chapter subheading is also a cue to signal content and organization (Schallert et al., 1988). The topics included in the text followed the CHED minimum requirements for Differential Calculus for engineering programs based on CMO No. 12, series of 2008 to ensure relevance of contents. Books and reference texts are valuable IMs that encompass all the topics to tackle in a particular course and need to be curriculum-based and substantial (Terano, 2015).

The topics were identified based on the objectives defined for every lesson with relevant problems and exercises that are specific to the topic. Experts usually examine the relevance of contents when evaluating the quality of school textbooks (Hartley, 2004). The suitability of the topic to the learner's ability was also considered in this text. The contents were developed in such a way that they are student-centered and goal-oriented with relevant activities (Reiser & Dempsey, 2012).

The clarity of the discussion in the text is mandatory and regarded as the most effective criterion for an effective IM (Gerson, 2000). In this simplified text, the presentation of concepts and theories is made simple, concise, and accurate for engineering students with sample problems and solutions that are developed based on the lesson objectives and illustrated clearly for easy understanding of the topic as Hartley (2013) and Gerson (2000) emphasized. Also, presenting the greater detail of the examples may have made the discussions clearer (Atkinson et al., 2000).

The exercises are presented at the end of every topic or subtopic in the simplified text with problems clearly stated. They were constructed based on the objectives defined for every lesson to ensure their relevance to the topic. They were sufficient for a given period allowing the students to learn more while they have to answer the questions. Paas and Sweller (2014) noted that it is important to provide sufficient exercises so as not to overload the learner's cognitive capacity. The suitability of the exercises to the level of the learner is therefore necessary. The study of Weiten et al. (1999) also showed that review exercises are useful and it is helpful to place them close to where they are referred to in the text. Students claim that the primary uses of the text are to help them answer the exercises or questions and to provide the supplementary reading (Hartley, 2013).

The acceptability of the text features is shown in Tables 1-4 and the responses of the evaluators are comparable. The objectives are highly acceptable as shown in Table 1. The results confirmed that the objectives presented include the cognitive, psychomotor and affective aspects of learning guided by the Bloom's Taxonomy. These findings are similar to that of Terrano (2015).

Several taxonomies were developed for higher education, but Finelli et al. (2015) claimed that Bloom's Taxonomy is still very widely used. Riazi and Mossalanejad (2010) for example used Bloom's as the framework of their evaluation study of course books. Razmjoo and Kazempourfard (2012) evaluated the learning objectives of course books but this time using the Bloom's Taxonomy Revised. Baktash and Talebinejad (2015) evaluated the acceptability of the developed Iranian series books also using Bloom's Taxonomy Revised to improve the quality of instruction.

Table 1. Acceptability of objectives.

Indicators	Weighted mean	Verbal interpretation
1. The cognitive, psychomotor and affective statements of the objectives.	4.86	Highly acceptable
2. Simplicity and attainability.	4.73	Highly acceptable
3. Suitability to the particular topic.	4.77	Highly acceptable
Overall Weighted Mean	**4.79**	**Highly acceptable**
SD	**0.0666**	
CV	**1.39%**	

Wilson (2014) discussed the revisions to Bloom's classic cognitive taxonomy by Anderson and Krathwohl published in 2001. The major differences lie in the comprehensive additions of how the taxonomy intersects and acts upon factual, conceptual, procedural and metacognitive different types and levels of knowledge. Nevertheless, it is important to note that the learning objectives in this simplified text can be classified into levels of complexity and specificity using the cognitive, psychomotor, and affective learning domains (Adams, 2015).

Table 2 shows that the contents of the simplified text are highly acceptable. Taking into account the indicators evaluated, the results confirmed that the general contents which include the topics, problems and exercises are aligned with the objectives of the lesson ensuring their relevance. The results also imply that the contents could provide learners the instructional strategies that would be effective for cognitive,

psychomotor, and affective learning since the objectives are developed using the Bloom's Taxonomy (Adams, 2015). The contents are highly acceptable considering that during the design phase of the study the CHED course outline was used as the guide to ensure that the required standards and competencies are met. The results further imply that the contents are suitable to the learner's ability and needs. Suitability is attained when the contents are student-centered and goal-oriented coupled with relevant activities (Reiser & Dempsey, 2012).

Table 2. Acceptability of the contents.

Indicators	Weighted mean	Verbal interpretation
1. Support of the objectives to the topics, problems and exercises.	4.86	Highly acceptable
2. The relevance of the problems and exercises on the topics.	4.77	Highly acceptable
3. The relevance of the problems and exercises on the objectives.	4.90	Highly acceptable
4. Suitability of the topics to the learning ability of the students.	4.90	Highly acceptable
5. Suitability of the discussions on the interests and needs of the students.	4.77	Highly acceptable
Overall Weighted Mean	**4.84**	**Highly acceptable**
SD	**0.0660**	
CV	**1.36%**	

The presentation and style of the simplified text as shown in Table 3 are highly acceptable. The results imply that the terms and the language used in the text are suitable to the level of student understanding. The findings also suggest that there is clarity in the discussions of the topic and the presentation of concepts and theories is simple, concise, and accurate. It can be further deduced from the results that the sample problems and solutions that are developed based on the objectives are clearly illustrated for easy understanding of the topic. Hartley (2013) emphasized that students have different needs and preferences in the learning process 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 IM (Gerson, 2000).

Instructional material plays a significant role in leaping intentions and plans to classroom activities by organizing contents and making them available, and by setting out learning tasks in a form designed to be appealing to students (Schmidt et al., 1997). Based on the three primary learning theories, the instructional strategies devised in the IM should aim for students to develop their cognitive potentials and be able to construct their meaning from new and prior knowledge (Keesee, 2012).

Table 3. Acceptability of presentation and style.

Indicators	Weighted mean	Verbal interpretation
1. Terms used	4.86	Highly acceptable
2. Language used	4.86	Highly acceptable
3. Clear presentation of the discussions	4.90	Highly acceptable
Overall Weighted Mean	**4.87**	**Highly acceptable**
SD	**0.0231**	
CV	**0.47%**	

Table 4 shows that the exercises in the simplified text are highly acceptable. The results confirmed that the exercises given are sufficient for the students to learn the concepts and theories of every topic in a chapter for a specified period. Providing sufficient exercises avoids overloading the learner's cognitive capacity (Paas & Sweller, 2014). The results also showed that the problems are clearly stated, and the exercises are suitable for the level of the learner. Dick et al. (2014) emphasized that the assessment must be parallel to and able to measure the learners' ability to perform what is described in the objectives. Problem sets will enhance the critical thinking of students. Terano (2015) stressed that in the tertiary curriculum, the focus 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 4. Acceptability of exercises.

Indicators	Weighted mean	Verbal interpretation
1. Sufficiency of the exercises given	4.90	Highly acceptable
2. Clearly stated problems	4.77	Highly acceptable
3. Suitability of the exercises to the level of the learner	4.86	Highly acceptable
Overall Weighted Mean	**4.84**	**Highly acceptable**
SD	**0.0666**	
CV	**1.38%**	

The overall results of the acceptability of the IM based on the features evaluated are shown in Table 5. All text features are highly acceptable which imply that the simplified text could be an effective instructional material for engineering students.

Table 5. Overall results of acceptability of the simplified text in Differential Calculus for engineering.

Indicators	Weighted mean	Verbal interpretation
1. Objectives	4.79	Highly acceptable
2. Contents	4.84	Highly acceptable
3. Presentation and style	4.87	Highly acceptable
4. Exercises	4.84	Highly acceptable
Overall Weighted Mean	**4.84**	**Highly acceptable**
SD	**0.0332**	
CV	**0.69%**	

Conclusion and Recommendations

The simplified text in Differential Calculus for Engineering follows the CHED minimum requirement for engineering programs. Objectives, contents, presentations and style, and the exercises are text features evaluated by engineering professors as highly acceptable which imply that the simplified text could be an effective instructional material for engineering students.

Further evaluation can improve the design of the material. Periodic revision of the simplified text can accommodate changes or updates in the CMOs. Item analysis may be carried out to improve the acceptability. The format of the material could be used as the matrix for the development of other instructional materials in related fields.

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