Validity of Engineering Mechanics Teaching Materials Using the Analysis, Design and Development (ADD) Stage

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Abstract. The foundations of mathematical analysis are taught in the Engineering Mechanics course, which helps students overcome material strength issues when accepting loads, both static loads and dynamic loads, where students are required to solve cases in the field by mastering three concepts, namely the concepts of mathematics, physics and mechanics. So far, problem-oriented engineering mechanics learning materials in the field have not been available. The aim of this research is to obtain the validity of engineering mechanics teaching materials based on problem solving in the field. The research began by developing engineering mechanics teaching materials. As a reference in developing teaching materials using the ADD (Analysis, Design, Development) development model which was adapted from the ADDIE model. Following the development of the teaching materials, specialists in the fields of material, learning design, and learning media evaluate the materials' validity. Distributing questionnaires is how the data gathering method for the validity assessment is implemented. A Likert scale is used in the validation assessment criteria by education material professionals, through a trial questionnaire with category scores 5, 4, 3, 2, and 1 are analyzed descriptively, namely very good, good, fairly good, poor, and very poor, respectively. The research results showed that for specialists in learning media, learning design, and materials, the viability values were 85.3%, 89.0%, and 90.0%, respectively. Consequently, it may be said that problem-based learning-based engineering mechanics teaching materials developed are very valid for implementation.

Keywords: Validity, Engineering Mechanics, ADD

1 Introduction

The era of globalization has changed the paradigm of world society today. This raises challenges so that humans today can continue to adapt to changing times. The demand to further increase innovation in all fields continues to strengthen, encompassing primary, secondary, and postsecondary education in the field of education. To raise the standard of instruction at a greater level, research is necessary in every effort to improve the quality. So that research can produce accurate information, appropriate research methods are needed.

The role of higher education in the globalization era is very important, especially in the science and technology development. Therefore, research-based higher education must

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encourage greater disclosure of knowledge that can improve human welfare. This era requires various university breakthroughs in producing competitive graduates [1].

College graduates needed in the era of globalization are individuals who are competent, well-trained and able to compete in the are of work world. To produce graduates who are competent and competitive, universities must innovate in the process of learning, one of which is by providing materials of teaching that can increse student competence. To improve the education quality and competence in the globalization era, it requires the consideration of the ease aspects of the use of teaching materials and application of technology [2].

Materials of teaching are a set of materials that designed and arranged systematically, so that the goals and competencies to be achieved in learning process can be achieved, where the function of the goal of instructional materials is to give students as many opportunities as possible to study on their own [3]. Furthermore, all items used to assist teachers or instructors in carrying out the process of learning in the classroom are considered teaching materials, according to the National Centre for Competency Based Training [4].

The learning process requires teaching materials which are learning tools both inside and outside the classroom, in other words, materials of teaching are a component of learning resources or physical vehicles that contain materials of learning that can attract students's attention to learn, in line with Yanti & Meriko's opinion which states that learning is a methodical procedure for creating different elements, such as lecturers and learning resources, learning strategies, teaching materials, students, and teaching materials [5]. Things that need to be considered when developing teaching materials are the characteristics of the course and the characteristics of the users, namely students. Students have been classified in the adult learner category [6].

According to Sunarya [7], better of materials of teaching have to meet the requirements as: 1. Materials of teaching are prepared as the applicable curriculum, 2. Materials of teaching are designed by experts in the fields, 3. These materials of teaching should be equipped by activities that supported by skills, thinking, process skills, attitudes and values, 4. Materials of teaching should reflect the aspects of presentation, materials and readability which are appropriate to the level of development of students.

Coretansikidi [8] states that the cone of experience principle is frequently applied while using learning media, necessitating the usage of media like textbooks and instructor-created instructional materials. It is believed that the instructional resources used in the process will encourage students to take a more active role in their own education and easily understand to the learning concepts explanation.

Making connections between the content helps facilitate effective learning from teaching materials with the environment of everyday life [9]. Connecting material with the environment can be done by presenting case studies in materials of teaching. Drawing from several definitions, teaching materials can be defined as instructional resources that are presented in an engaging and methodical manner to facilitate independent study. Physics includes engineering mechanics courses, where physics is frequently seen as a challenging subject. The findings demonstrated that pupils struggled to comprehend the physics. The majority of students reported that these challenges frequently occurred during their physics classes, particularly while resolving field problems [10].

The Engineering Mechanics course is a mandatory course in the Mechanical Engineering Education Department, Unimed Faculty of Engineering. The Engineering Mechanics course is a introductory course on mathematical analysis for problem solving material strength problems in receiving loads, both static loads and dynamic loads. This course is presented in 3 credits which are presented in the second semester. In the semester two, Students are still

getting used to the university's learning system. The course examines the concept of material strength planning in a form of construction, machining, and calculation of shaft design (solid & cavity) on the machine. Planning includes the calculation of compressive load, tensile load, shear load, and twisting strength.

The subjects that will be described during lectures include: (1) Basics of mechanics: loading and deformation, stress, strain, Hooke's law; (2)Twisting: shear stress distribution, design examples; (3) Deepening of matter: deformation, stress, strain, Hooke's law and twisting; (4) Crooked loading: normal stress distribution, shear stress distribution; (5) Crooked loading: shear current, case in point; (6) Stress and strain analysis: analysis methods, Mohr graphical/circle method.

In activities of learning, material of mechanics is combined between theory and practice. These require the development of teaching materials that visualize cases in the field to strengthen student understanding [11]. Understanding of mechanics courses can be attained by teaching occurrences and issues that frequently arise in daily life. The easiest material to present in mechanics teaching materials is case studies. On the basis of the description above, it is considered important to develop engineering mechanics teaching materials that can increase student competence in solving engineering mechanics cases in the field.

The mechanics curriculum integrates theory and practice in a cohesive manner. To improve student's comprehension, instructional materials that depict real-world situations must be created. Some notions of the development model as described provide clues, that a development model aims to provide direction for efforts to improve and improve the quality of education and learning. Development of learning consists of at least five main activities, such as: (1) Learning design outcomes are implemented through the following steps: (2) analyzing learning conditions and learner needs; (3) designing a series of specifications that are efficient, effective, and relevant to the environment; (4) developing all learning materials and material management; and (5) formative and summative evaluation of development results.

The implementation of development results will not run optimally, effectively, and attractively if one of the subcomponents is not done properly and correctly. The development model is also a means of facilitating a new product development so that it is more measurable to increase the effectiveness of the product developed.

Development and design activities are planned activities and require reference, in this research using the development of ADD (Analysis, Design, Development). In this context, the development model functions as a point of reference, a guide, or a directive that the designer can utilize when creating the learning system to ultimately provide an implementable and quantifiable teaching material development design.

The aim of this study is to obtain the validity of engineering mechanics teaching materials developed using the ADD model. In addition, the results of this research and development can provide benefits: (1) As a reference to optimize the learning process of the Engineering Mechanics course; (2) Increase knowledge in the field of Engineering Mechanics, especially in solving cases in the field (case studies); (3) As a reference for the development of learning materials in other courses with different learning models and strategies.

On the basis of the description above, it is considered important to develop engineering mechanics teaching materials using the ADD model that can increase student competence in solving engineering mechanics cases in the field.

2 Research Methods

2.1 Research Methods and Steps

Research and development (R & D) is the research methodology employed in this study, and module development is carried out using the ADD (analysis, design, development) development model from Gagne. The validity of teaching materials is obtained from 3 stages, namely analysis, design and development (ADD). The stages in the ADD model [12], are (1) Analysis, conducting needs assessment; (2) Design, design phase, assessment instruments, analysis of subject, lesson plans and selection of learning media.; (3) development is the process of turning a draft design into reality or a usable product.

The ADD model has two advantages: (1) it presents a more thorough and organised explanation; and (2) it incorporates expert assessment in its creation, allowing learning tools to be altered prior to field trials based on assessments, recommendations, and expert feedback.

Experts in the fields of learning design, learning media, and engineering mechanics served as validation test subjects for the creation of this instructional resource. Students enrolled in engineering mechanics courses at Medan State University's Department of Mechanical Engineering Education, Faculty of Engineering, are the intended audience for the instructional materials. The competence of subjects with expertise in engineering mechanics lecturers who instruct engineering mechanics courses is the basis for choosing material specialists. Expertise in learning media technology and learning design, specifically educational technology lecturers are the basis for choosing learning media and learning design experts.

2.2 Instruments and data collection

The instrument is in the form of a questionnaire to determine the quality of teaching materials according to validators and students. This instrument was prepared based on the Science Textbook Assessment Standards issued by the Book Center of the Ministry of National Education in 2003 which have been modified.

How to Collect Data (1). Data regarding the competencies required in engineering mechanics courses is collected through analysis of the Semester Learning Plan (*Rencana Pembelajaran Semester*). The needs analysis was carried out with members of the research team as instructors of the engineering mechanics course at the Department of Mechanical Engineering Education, Medan State University. (2). Data regarding the quality of teaching materials for engineering mechanics courses based on competency analysis seen from the material, media presentation and learning design from validators using a questionnaire that has been prepared. Data is obtained after the validator validates the teaching materials that have been prepared, after the teaching materials are revised based on expert validation, the teaching materials are ready for students to use in learning activities.

The present study employed a qualitative analysis to examine the data gathering method. The instruments produced for data collection are associated with the data collection procedures implemented at each research step, specifically: (a) a set of inquiries utilised as an observational questionnaire, (b) A Likert-scaled questionnaire from the Learning Object Review Instrument (LORI) version 1.5 was utilised for expert development and validation [13].

2.3 Data Analysis Technique

Descriptive analytic methods were used to carry out the data analysis procedure, which involved first analysing quantitative data from expert test questionnaires and field tests and then providing a qualitative interpretation. The next stage after obtaining the data is to analyse it. To analyze data from the questionnaire, calculate the score for each sub-variable using the formula:

$$X = \frac{\Sigma x}{N} \quad (1)$$

Information:

X = Score Appropriateness
Σxx = Amount score each sub-variableN
N = Amount sub-variable

2.4 Validity of Teaching Materials

Descriptive analysis techniques are used to analyse data, namely by analysing quantitative data from expert test questionnaires and field tests and then qualitatively interpreting the results. After the data is obtained, the next step is to analyze the data. To analyze the data from the questionnaire, the following steps are performed: (1) Validate media to media experts, material experts and learning design experts; (2) Validation questionnaires filled in by media experts, material experts, and learning design experts are checked, if there are still desired discrepancies in validation, the media is corrected; (3) Quantify the validation assessments of media experts, material experts, and learning design experts according to the predetermined assessment weights: (4) After that, distribute questionnaires to students to be filled, then checked, and compiled according to the respondent code; (6) Quantify questions by giving scores according to predetermined weights; (7) Tabulate the data.

Based on previous data analysis, the qualitative percentage range and validity criteria can be determined, as shown in Table 1.

Table 1. Validity Criteria for Engineering Mechanics Teaching Materials [14]

No.	Interval Score	Criteria
1	1.00 – 2.49	Invalid
2	2.50 – 3.32	Fairly Valid
3	3.33 – 4.16	Valid
4	4.17 – 5.00	Very Valid

If the survey's results fall into the "Very Valid," "Valid," or "Fairly Valid" categories, this instructional material is considered valid. Prior to beginning the process of gathering field data, researchers need to create data assessment standards or criteria. Equivalent to the validity criteria with a 2.50 validity score limit since, in Sriadhi's opinion, product development findings can be considered valid if the data analysis that results achieves 50% of the validity required for research data processing qualifies.

3 Results and Discussion

3.1 Results

Analysis results were obtained from conducting a needs assessment (needs analysis) through questionnaires and observations. Questionnaires were delivered to data subjects, namely 35 (thirty five) students who had taken engineering mechanics courses. Observations were carried out to find out the learning process directly in the Department of Mechanical Engineering Education, Medan State University. The results of the observations concluded that it was necessary to develop teaching materials for engineering mechanics courses based on stakeholder needs.

To analyze the need for learning materials, a Focus Group Discussion (FGD) was carried out. The FGD participants consisted of engineering mechanics course instructors and vocational school engineering teachers as well as graduate user stakeholders. From the results of the discussion, conclusions can be drawn, which are described as follows: (1) Material that is relevant to the learning objectives

The material for the Engineering Mechanics course must start from Understanding Engineering Mechanics, Mechanics of Rigid Bodies, Equilibrium Concepts, Application of Equilibrium Concepts, Portal Structures, Truss Construction, Mass Moment of Inertia, Application of Moment of Inertia; (2) Useful presentation techniques to meet learning objectives It is suggested to convey learning using a variety of techniques depending on the qualities of the students. Learning presentation methods are varied, including interactive question and answer, group discussions, group presentations, participatory lectures, final project assignment consultations, and group presentations for each group, in order to make learning more engaging and to meet competencies and learning objectives; (3) Applicable Learning Techniques. In order to meet the learning objectives outlined in Outcomes Education (OBE), creative learning strategies that engage students critically and actively and generate learning materials that inspire creativity are required. When using a project-based learning approach, students must be able to create a final learning product by investigating as much data as you can from diverse sources, talking about it, and creating a product that is focused on case studies. Project-based learning methodologies are pertinent to the intended learning objectives; (4) Assessment of learning Participants in the FGD proposed using written tests for either individual or group assessment. Pre-test questions are used to assess students prior to learning Engineering Mechanics, and post-test questions are used to conclude the learning process. As part of the continuous learning process, evaluation is also done through individual independent tasks, journal and book reviews, and group discussions on case studies. Preliminary research findings indicate that creating instructional materials for courses in engineering mechanics is essential to provide project-based learning techniques and case studies top priority in order to meet the demands of students.

Based on the material analysis that has been carried out, teaching materials have been produced consisting of 6 chapters, namely definition of engineering mechanics, mechanics of rigid body, concept of balance and application, portal structure, rod frame construction, moment of inertia.

The teaching materials presented are constructivist, interesting, cover all the competencies that students must have, provide broad insight into engineering mechanics material which is entirely based on stakeholder needs. The validation results of the teaching materials that have been prepared are revised, starting from revisions by specialists in learning media, learning design, and materials.

3.1.1 Development Results

The development of materials of teaching is designed from the results of needs analysis and learning analysis. Then, at this development stage, validation is carried out by material experts, learning design experts and learning media experts.

The materials of learning that lecturers select and that students are required to study should include content that genuinely helps students meet the basic skills and competency criteria. The general steps involved in choosing teaching materials are as follows: (a) determine the elements found in the competency standards and basic competencies, which serve as the reference or references for choosing materials; (b) determine the kinds of teaching materials; (c) choose materials that are pertinent to or appropriate for the previously identified competency standards and basic competencies; and (d) select the source of teaching materials.

3.1.2 Material Expert Validation

The content of the learning material, how it is presented, and the assessment instruments make up the three (three) components of material expert validation. The outcomes are displayed in Figure 1.

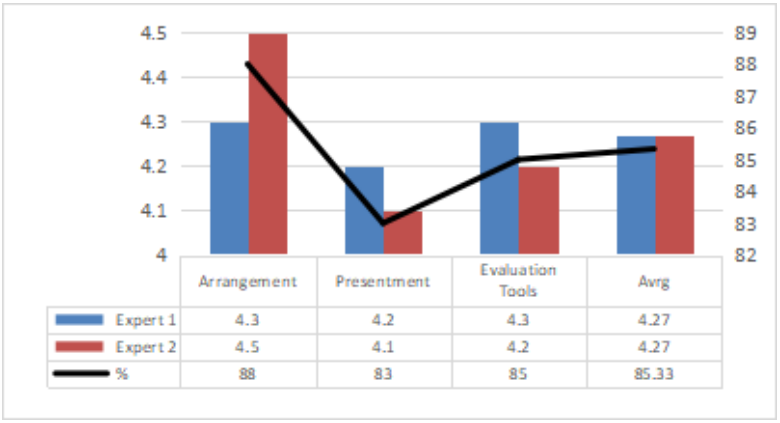

Fig. 1. Average Material Expert Validation Results

Of the three aspects assessed by material experts, the average score obtained was 4.27 or 85.3% and it was included in the very good category.

3.1.3 Validation of Learning Design Expert

The four components of learning objectives, learning techniques, material preparation, and assessment tools comprise the validation of learning design specialists. Figure 2 displays the assessment of the learning design expert.

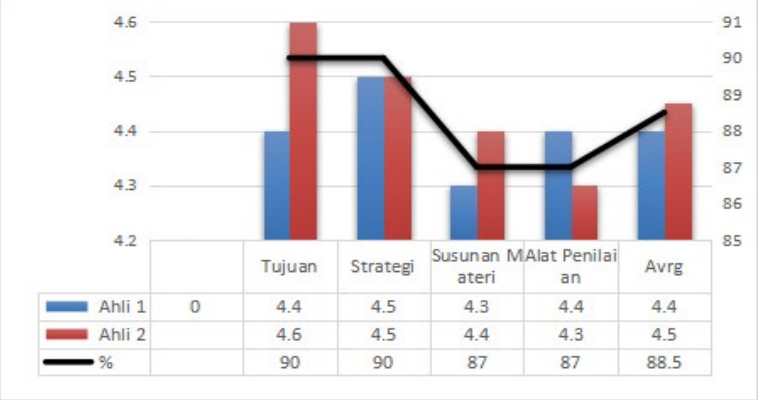

Fig. 2 Average Validation Results from Learning Design Experts

The average score given by learning design experts for 4 (four) aspects of the assessment is 4.45 or 89.0%, thus the validation assessment of learning design experts is in the very good category.

3.1.4 Validation of Learning Media Expert

Setting, cover, and visual illustration are the three (three) components of learning media specialists' validation. Diagram in Figure 3. displays the learning media specialists' evaluation.

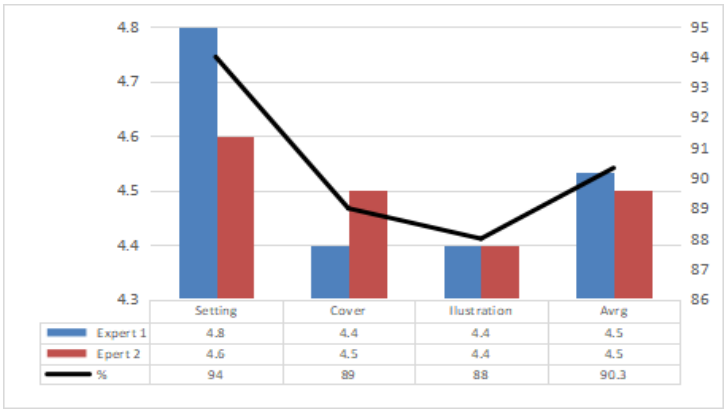

Fig 3. Average Learning Media Expert Validation Results

Experts in learning media awarded it an average score of 4.5, or 90.0%, for validation, placing it in the legitimate category. Table 2. displays the validation results from specialists in learning design, learning media, and materials.

Table 2. Validation Score from Experts

No	Expert	Average Score	(%)
1.	Materials Expert	4,27	85,3 %
2.	Learning Design Expert	4,45	89,0 %
3.	Learning Media Expert	4,50	90,0 %

3.2 Discussion

This research has produced valid teaching materials for engineering mechanics courses by following the research steps of Analysis, Design Development (ADD) with several revisions to produce teaching materials that are valid. The results of the material expert validation consist of several components including a section regarding the discovery of important concepts in a constructivist way by students, the results are in the very valid category, this happens because the material has maximally helped students to learn independently, explanations of sentences contained in the teaching materials, as well as descriptions the formulas are very good. The suitability of the material with the formulated competencies and the clarity of the material in the teaching materials are included in the very good category.

The teaching materials developed base on a strategic function for the teaching and learning process. It can assist lecturers and students in activities of learning, furthermore the lecturers do not need to present too much material. Besides that, materials of teaching can replace some of the roles of lecturers and support individual learning independently. It will have a positive impact to lecturers, because the part of their time can be devoted to guide learning of student. The positive impact for students is that they can reduce the dependence on lecturers and get used to independent learning.

Materials of teaching are very different from textbooks. Good materials of teaching are designed according to the principles of instructional. Materials of teaching are usually equipped to the guidelines for students and teachers. Guidelines are useful for making it easier to students and teachers who use the materials of teaching. This is in line with the opinion of Murniati & Muhammad Muslim [15].

The development of this teaching material still has several limitations, including the subjects involved in the testing process are still very limited, namely students from the Department of Mechanical Engineering Education, Medan State University, so the quality of the teaching material developed needs to be tested again on subjects in different departments and different universities.

4 Conclusion

From this research, there are two conclusion points that can be outlined, namely:

a. The needs analysis shown the currently textbooks/modules/dictates/ engineering mechanics learning materials that suit stakeholder needs are not yet available, thus it

is necessary to develop engineering mechanics teaching materials. The development of engineering mechanics teaching materials produces teaching materials that suit stakeholder needs with detailed material definition of engineering mechanics, mechanics of rigid body, concept of balance and application, portal structure, rod frame construction, moment of inertia.

b. The validity of the developed engineering mechanics teaching materials is declared valid for implementation with very valid criteria. This is proved by the validation results for material experts, learning design experts, and learning media experts are 4.58 (91.6%), 4.48 (89.6%), and 4.42 (88.4%), respectively. From the expert assessment, the average score was 4.42 (90%), including very valid criteria. In this way, the engineering mechanics teaching materials developed can increase student competence to solve cases in the field.

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