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Design and Validation of a Competency Assessment for Electrical Power Systems in Engineering Education

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ABSTRACT

This research aims to design, develop, and validate a competency test for assessing students in the Electric Power System field. Given the need for rigorous, competency-based assessments in Electrical Engineering, this study addresses the gap by creating a test aligned with specific graduate competencies. The competency test was developed using the Borg and Gall development model, following seven systematic steps. Test items were structured around the competencies expected of graduates from the Electrical Engineering program, categorized according to Bloom's taxonomy levels 4, 5, and 6 to assess higher-order cognitive skills. A two-phase trial was conducted with 80 students to refine and validate the test. Validation by material and evaluation experts rated the test highly feasible, with scores of 71.0 and 45.55, respectively. Empirical validity testing, using biserial correlation, confirmed that all items were valid (correlation > 0.302), and the reliability test via KR-20 yielded a high reliability coefficient (α = 0.854). Item difficulty was balanced, with 10% easy, 83% moderate, and 0.7% difficult questions. Item discrimination levels were 20% moderate, 33% good, and 47% very good. The results suggest that the competency test is a reliable and valid tool for assessing critical competencies in Electric Power Systems, effectively distinguishing between different levels of student ability. This validated competency test provides a robust assessment tool, supporting competency-based education in Electrical Engineering. Its design and validation process can serve as a model for future competency assessments in technical disciplines.

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1. INTRODUCTION

The purpose of preparing and developing the competency test is to develop question items to find out the extent of students' mastery of the lecture material before conducting a thesis exam or passing the bachelor's degree in Electrical Engineering. One of the requirements for students to take the thesis exam for the Electrical Engineering study program at Medan State University is to have passed the competency

test in the field of electrical power systems. The implementation of competency tests is carried out regularly and on a scheduled basis, namely twice in one semester. This requires the availability of test tools that meet the requirements as an assessment tool, namely valid, reliable question items, suitability of the difficulty level of the questions and good question differentiation.

The preparation and development of competency test questions is guided by the curriculum of the Electrical Engineering Study Program. The curriculum of the Electrical Engineering study program is developed based on the curriculum structure of Fortei (Indonesian Electrical Engineering forum)(Syaichu & Akademik, 2018), IABEE (Indonesia Accreditation Board for Engineering Education) curriculum standards and relevant local content. The grouping of courses in this curriculum consists of the group of mathematics & basic sciences, engineering sciences, other relevant topics and engineering design. The preparation of competency test question items is selected from the study of engineering science group courses and other relevant topics

Courses included in the engineering science group and other topics include: electrical circuits, basic and digital electronics, electrical machinery, lighting and electrical installations, and electrical power system networks (Andrei et al., 2017). These five courses are important materials in the development of science and technology of electric power systems and their application in industry and society(Guedes & Encarnacao, 2018), (Lapa et al., 2020), (Khulda & Wandebori, 2020), (Chang & Shih, 2020). These five courses in the distribution of the curriculum of the Electrical Engineering study program curriculum are carried out in the second and third years, so that students participating in the competency test have taken lectures in this course.

The course that is the basis for the preparation of the competency test from one, in the preparation of question items must consider various things such as the planned time allocation, the scope of the material, and the assumption of the time to complete each question item. The allocation of test time is generally around 90-100 minutes. The composition of the competency test material comes from five courses, so the preparation of question items is carried out proportionally to represent the five courses. The assumption of the time to complete each item depends on the type of question and the difficulty level of the question. The difficulty level of question items is based on Bloom's taxonomy which is oriented to the type of high order thinking questions, so that the question items are arranged in the realm of application, analysis, evaluation and creation in Bloom's taxonomy (Meda & Swart, 2018).

Competency tests are an evaluation tool, especially the competency ability of students that can reflect the results of the real and accurate assessment. This can be achieved if the test question items meet the requirements of a good test. Good test requirements include the validity of question items, test reliability, equivalence of the proportion of difficulty levels of question items and having a minimum good question differentiation. Question items are said to be valid if they show a level of accuracy in measurement, while reliability indicates the level of test consistency in measurement (Weiss, n.d.). The validity of the question items consists of the validity of the content and the validity of the construct. . The validity of the content of the question items describes the scope of the material and the questions have met the requirements based on the assessment of material experts and in accordance with the principles of assessment according to evaluation experts and material experts. The validity of the construct is able to explain that the question items in the validity test statistically meet the validity index. Test reliability describes the level of persistence or consistency of the test in measurement, so that the competency test must also meet the reliability coefficient in accordance with the test standard.

The Index of difficulty of question items in the test shows the extent to which the test taker can answer the question correctly, so that the difficulty level of the question is seen from the test taker's ability to answer the question items correctly. The difficulty index of questions (p) is divided into three categories, namely easy, medium and difficult questions. The difficulty level of the questions is the basis for determining the category of test participant graduates. The difficulty level of the question item ranged from 0.00-1.00, this shows that the higher the value of the item difficulty index, the easier the question and vice versa. This competency test aims to measure the competence of students who will graduate in

the field of electric power systems, so the preparation of question items based on a normal curve leaning to the right, namely the proportion of medium and difficult questions, more and fewer easy questions.

In addition to the level of difficulty, another requirement item to get a good competency test is that the question item has a minimum positive discrimination index in the medium category (D=< 0.2). The difference test showed that the question items could distinguish between the upper group participants who could answer correctly and the lower group who answered incorrectly (Kadam et al., 2021). This is because multiple-choice tests often give rise to guessed answers whose answers may or may not be correct. Therefore, the competency test must have a discrimination index of at least the medium category, so that the question items can distinguish whether the participant has low, medium or high ability.

Based on the description above, the development of competency tests in order to achieve the goal of measuring the actual competency ability of students, in the preparation of question items must meet all the requirements above, namely the validity of significant question items, high reliability, the proportion of the difficulty level of the item in accordance with the normal curve and the difference of the question at least in the high category. This is important because the competency test developed can measure the actual competency ability of students, so that the grouping of competency test results in the category of poor, good and very good can be scientifically accounted for (Eckes, 2012) .

In conclusion, the development of competency tests for Electrical Engineering students at Medan State University addresses a critical gap in effectively assessing students' mastery of essential knowledge before they undertake their thesis examinations. While competency assessments are a common requirement in many engineering programs, there is a lack of standardized, rigorous competency testing specific to the knowledge areas relevant to electric power systems. This research introduces a structured approach to creating competency test items, grounded in the curriculum developed according to Fortei, IABEE standards, and local academic requirements. Through this process, the study aims to establish question items that are valid, reliable, and appropriately challenging, ensuring they provide a meaningful differentiation of student abilities. The central research questions focus on understanding the elements necessary for constructing an effective competency assessment, particularly regarding the alignment of test items with Bloom's taxonomy levels of higher-order thinking skills. The significance of this research lies in its potential to enhance educational assessment practices within engineering disciplines, offering a validated model for other institutions aiming to implement competency-based evaluation methods that accurately reflect students' preparedness for professional practice.

2. METHODS

The development of the electrical power system competency test in this study uses Research and Development (R&D) from Gall, using a seven-step research procedure, namely: analysis of the need for standard test preparation, feasibility study of planning to build a model and build a standard test model of competency test, limited standard test trial, analysis of instrument items and improvement of standard test instruments, the 2nd instrument trial, and the determination of the competency test standard test. The research sample is Electrical Engineering students in the 2019-2020 entry year as many as 40 students in the first trial and 40 students in the second phase of the trial.

The variables of this study are the question items of the student competency test standard test consisting of 5 groups of questions, namely: 1) the group of questions about electrical circuits; 2) the group of questions about electric machines; 3) distribution group; 4.) distribution and transmission groups; and 5) installation and illumination groups. Question items are arranged in the form of multiple-choice questions based on levels C4, C5 and C6 according to Bloom's taxonomy (Akhan & Öztürk, 2021) .

The validity test of question items uses the validity test of content and construct validity. The validity test of the content by material experts to review the level of feasibility of competency test questions based on the following aspects: (a) content feasibility, (b) linguistics, (c) contextual, and (d) presentation. The questionnaire to test the feasibility of the material consisted of 16 questions on a Likert scale of 1-5. The validity of the content for the level of feasibility is based on the assessment of evaluation experts with

assessment indicators: (a) test construction, (b) question item level, (c) format, and (d) graphics. The questionnaire to test the feasibility of the evaluation consisted of 10 questions on a likert scale of 1-5. The criteria for the level of feasibility of competency test questions are based on the results of the assessment of material experts, and the evaluation is based on the standard assessment criteria of the normal curve as shown in tables 1 and 2 below.

The validity analysis of the research construct uses Biserial Correlation analysis because the form of the question is multiple choice with the provision that the question item is declared valid if the biserial r value >0.304 (n=40, df 5%). Reliability analysis test using KR-20 for multiple-choice questions. The competency test is declared feasible if the reliability value of the test ≥ 0.7 (good or very good). The difference of the questions used the criteria of the question with a difference index of ≥0.3 (good and very good), while the difficulty level followed the normal curve distribution, namely 25% of the easy category questions (p>0.75), 50% of the medium category questions (0.25≤p≤0.75), and 25% of the difficult category questions (p<0.25).

Table 1. Criteria for Assessing Subject Matter Experts quantitatively based on the value of normality.

No	Score	Criterion
1	69.34 and above	Highly Worthy
2	58.67 to 69	Proper
3	37.33 to 58	Quite decent
4	26.6 to 37	Not eligible
5	Under 26	Very unworthy

Table 2. Expert Assessment Criteria Evaluate quantitatively based on the value of normality.

No	Score	Criterion
1	69.34 and above	Highly Worthy
2	58.67 to 69	Proper
3	37.33 to 58	Quite decent
4	26.6 to 37	Not eligible
5	Under 26	Very unworthy

3. FINDINGS AND DISCUSSION

3.1. Analysis item test development

The development of the electric power system competency test in this research used Research and Development (R & D) from Gall to develop a standard instrument for the electric power system competency test (Gall et al., 1996). Research procedures include analysis of the needs for preparing standard tests, feasibility studies, planning to build models and compiling standard test models for competency tests, limited standard test trials, analysis of instrument items from trial results and refinement of standard test instruments for competency tests, trial of the second instrument, and determination of competency test standard tests.

Development of competency test instrument items based on literature review, study program learning, and study program curriculum. Based on this, the steps in development include:

3.1.1 Preliminary studies

The preliminary study aims to collect various information related to product development, which includes:

1) Preliminary Analysis

The initial analysis or identification of needs aims to determine the basic problems that arise in preparing standard tests for electrical power system competency tests, especially the scope of competency test material. Initial analysis to obtain an overview of the scope of material,

implementation allocation, and level of competency skills that must be mastered. This will make it easier to determine and select a standard competency test grid which will be developed based on the syllabus and curriculum of the Electrical Engineering and Electrical Engineering Education Study Program. Based on the description of the facts of the problem, it is necessary to develop a standard test for electric power system competency tests in the cognitive field, so it is hoped that the existence of a standard electric power system competency test will show the level of student competency.

2) Competency Test Needs Analysis

The competency test analysis aims to assess the level of student competency abilities after graduating from the Department of Electrical Engineering Education in the field of electrical power systems. Competency tests are carried out more than once a year, so a question bank that is sufficient and varied and can measure what should be measured is needed.

3) Formulate Goals

The formulation of standard test objectives is used to determine how to develop standard competency tests in electrical power systems which include abilities in the field of electrical circuits, electrical machines, electrical power networks according to the research object. The formulation of this objective is the basis for compiling and designing standard competency tests.

3.1.2 Feasibility study

The feasibility study aims to conduct an initial investigation into the alignment and effectiveness of the proposed standard competency tests in evaluating the competency levels of Electrical Engineering students, specifically in the domain of electrical power systems. This study will assess whether the planned test structure, content, and difficulty levels are well-suited to accurately measure the core competencies expected of graduates. Feasibility considerations include evaluating the test's ability to reliably differentiate between varying levels of student knowledge and skill, its adaptability to real-world application scenarios, and the extent to which it fulfills the program's academic and professional standards for competency assessment. By ensuring that the competency test meets these criteria, the study will validate the test's potential for practical implementation in evaluating the competencies of electrical engineering graduates, providing a tool that not only assesses student achievement but also aligns with industry standards and professional requirements for the field. This feasibility analysis is critical, as it establishes the foundational evidence needed to support the competency test's adoption within the curriculum, ultimately enhancing the quality and relevance of engineering education.

3.1.3 Planning standard test instruments for competency tests

The design of a standard competency test for Electrical Engineering involves meticulous planning and development of test items that accurately measure the competencies required in the field. This design process builds upon two foundational stages: a preliminary study and a feasibility study. These initial stages inform the development by assessing the needs and feasibility of the test, ensuring that the test aligns with curriculum objectives and accurately reflects the expected competencies of graduates.

The first step in the design phase is the preparation of a competency test outline. This outline encompasses the planned question items and defines the scope of the test content. It ensures that the questions meet established assessment standards and are suitable for objectively evaluating student competencies. The outline serves as a blueprint for structuring the test to fulfill its intended purpose as a reliable assessment tool.

Next, the content of the competency test is tailored to align with the KKNI-oriented curriculum of the Electrical Engineering Study Program. This curriculum dictates the core subjects to be covered, including essential topics such as electrical circuits, power networks, and electrical machines. These

subjects form the foundational knowledge areas within electrical power systems, ensuring that the competency test evaluates critical skills necessary for professional practice.

In terms of format, the test follows a standard multiple-choice structure. Multiple-choice questions are chosen for their objectivity in scoring, which aids in accurately representing students' competency levels without subjective interpretation. This format adheres to established principles for standardized competency assessments and supports the efficient evaluation of large student groups.

The development of test items (Draft I) considers the profiles of Electrical Engineering graduates, who may work in roles such as managerial and technical practitioners in power systems, industry and business services, or engineering and optimization. For Electrical Engineering Education graduates, the test also evaluates competencies relevant to roles as prospective educators in vocational institutions. Based on the program's learning outcomes and input from subject matter experts, the test items encompass core competencies across key areas: electrical circuits, electronics, electrical machines, illumination and installation, power system analysis, and microprocessors. Each of these subjects is integral to the electrical power systems domain, covering foundational knowledge and practical applications essential for professional success.

Finally, the competency test is organized into a structured script, forming a comprehensive question bank. This includes a cover, table of contents, foreword, test grid, and closing section, along with a bibliography based on previously determined study materials. The presentation of the competency test follows standardized assessment principles, ensuring that each component is well-organized and accessible, thereby supporting a smooth testing process. This systematic approach to designing the competency test underlines its potential as a reliable measure of students' preparedness, rigorously aligned with educational standards and the professional demands of electrical engineering.

3.1.4 Development Competency Test Question Items

Based on the draft obtained, it is continued with the development stage which is the initial stage in producing standard competency tests. This development stage is based on draft teaching materials that have been prepared and then validated by material experts on electrical power systems, namely a group of lecturers in the field of electrical power systems and related subjects to obtain input for improving standard competency test instruments.

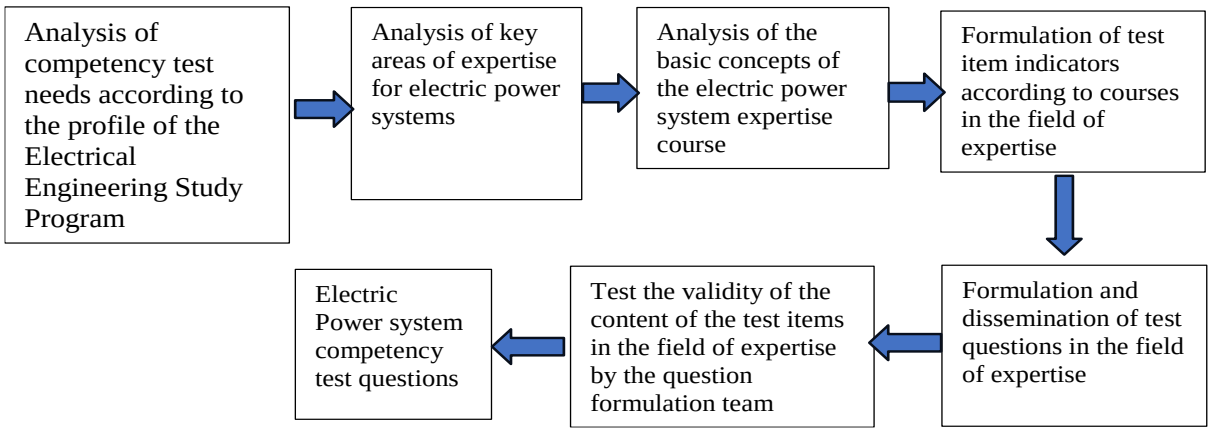

Figure 1. Steps of the research

The results of the development of items about the electric power system in the form of competency tests were carried out, including content variation tests, construct validity tests, item difficulty tests, difference tests, and reliability tests. The results of validation by material experts and evaluation experts

on the competency test are in the very feasible category with an average score of 71.0 > 69.4 and an average score by > evaluation expert of 45.5 > 43.3 as shown in table 3. Thus, the validity of the content of this competency test has met the requirements and is suitable for use in student competency tests.

Table 3. Validator Assessment Results

No	Judgment	Average	Value Range
1	Expert Evaluation	71.0	>69.4
2	Subject matter expert	45.5	>43.34

The first trial was carried out on 40 students for validity and reliability tests, grain difficulty tests and differentiation tests. Data analysis was carried out with the SPSS 25 and Exel programs on 30 questions, 11 questions were obtained that did not meet the requirements both in terms of validity, difficulty and differentiation, namely: no 1, 2, 5, 7, 8, 9, 10, 13, 20, 21 and 24 with values as in figures 2, 3 and 4. Question items that do not meet the requirements for validity, item difficulty, and differentiation tests are revised or replaced with new questions to meet the requirements of question items. Replacement question items are arranged with the same indicators as the question items that do not meet the requirements so that the proportion of the scope of the questions does not change and is in accordance with the indicators set previously.

The question items that have been replaced are then carried out a second trial in Electrical Engineering Study Program students as many as 40 students in the 2019 and 2020 entry years. The analysis of validity, difficulty and differentiation was carried out on the results of the second trial showed that all items of the competency test had met the requirements, namely with the validity value of each question item greater than the significance value (r > 0.302), and the reliability value of the test was included in the very good category (α = 0.854). The analysis of the difficulty level of the item was in accordance with the purpose of the competency test with a proportion of 10% easy questions, 83% moderate questions and 0.7% difficult questions. The difference in question items with a proportion of 20% is moderate, 33% is good and 47% is very good. The results of the first and second trial empirical validity tests (validity, difficulty and differentiation of each question item) as a whole as shown in figures 2, 3, and 4.

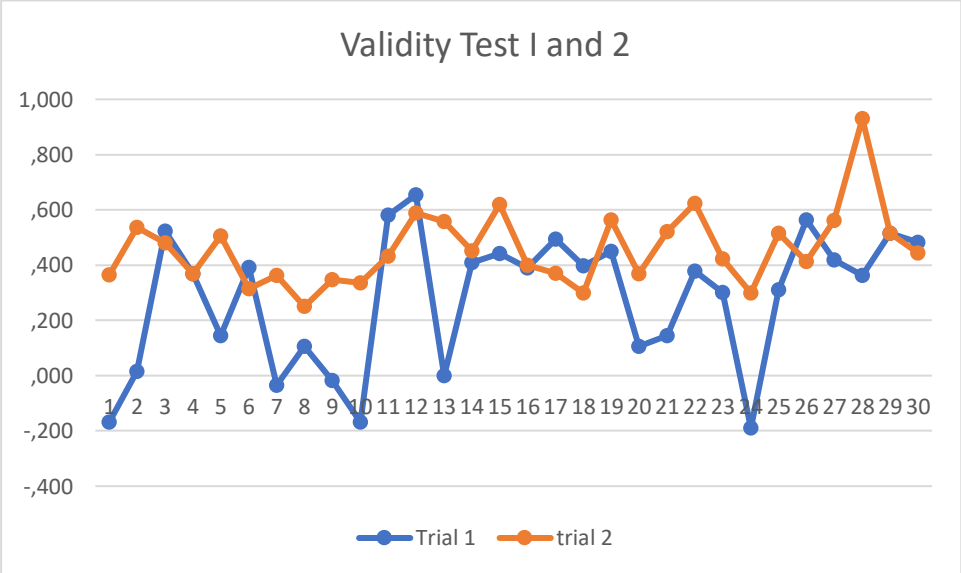

Figure 2. Graph of Empirical Vadity Test Results in Trial I and Trial II

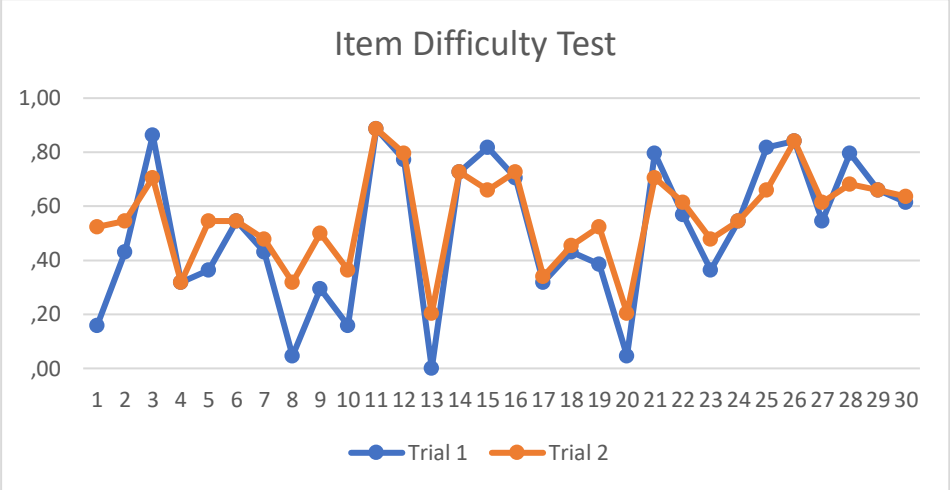

Figure 3. Graph of difficulty test of question items

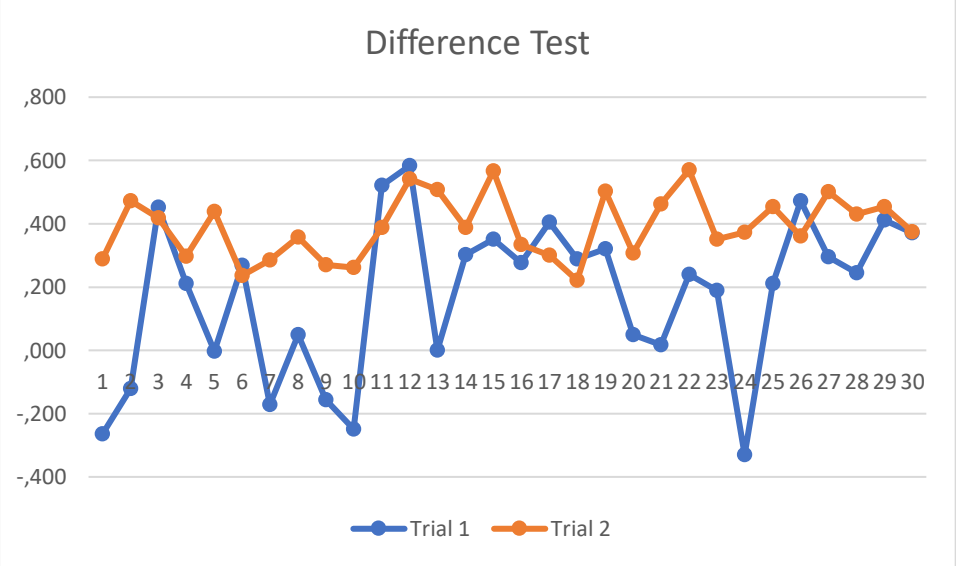

Figure 4. Graph of Difference Test Questions

Discussion

The competency test is needed to find out the extent to which prospective graduates of Electrical Engineering have the ability to have basic knowledge of electrical engineering as a foundation for further development. Competency tests are used to ensure that graduate students have achieved the competencies needed as professionals in the electric power system and are ready to develop in accordance with the development of science and technology in the field of electric power systems. Competency testing of students graduating from the Electrical Engineering Study Program is very important to find out the extent of the student's abilities (Sutopo et al., 2024)

The results of the competency test can be used as evaluation material in the learning system in the Department of Electrical Engineering Education. The percentage of students who have not graduated, graduated in a good category, or graduated in a very good category shows the competency ability of students who will graduate in the Electrical Engineering Study Program. If the percentage of students who repeat is relatively small, it can be an indicator that the learning process in the study program is

going well, on the other hand, if the percentage of students who repeat is still quite large, there needs to be an evaluation of the learning activity process.

The question items in the competency test are developed based on study materials from several main subjects, namely electrical circuits, basic electronics and digital, lighting and electrical installations, distribution and transmission networks, and electrical machinery. This course is the basis for the development of electric power systems and its application is very wide in industry and society (Betin et al., 2014). Thus, as a bachelor of electrical engineering, students are required to have abilities in main courses, especially electrical circuits, basic electronics and digital, electrical illumination and installation, distribution and transmission networks and electrical machinery.

The development of competency tests to be in accordance with the objectives as a measuring instrument, namely measuring according to what is measured, also considers the purpose of measuring the level of student ability. This requires assessment requirements, namely valid, reliable, difficulty level of question items, and question differentiation (Ma et al., 2022), (Erviana et al., 2023). The suitability of the scope of the material in the question items is validated by material experts, while the suitability as an evaluation tool is validated by evaluation experts. The competence of engineering graduates in Indonesia's national competency standard is level 6 and in accordance with the needs of industry or society, the question items are arranged based on the bloom taxonomy in categories 4, 5 and 6 (Meda & Swart, 2018).

In addition to fulfilling the content analysis related to the scope of the material in accordance with the purpose of the competency test, it also fulfills the analysis of the empiric test, namely validity, reliability, difficulty of question items, and question differentiation. Validity and reliability are related to the level of validity (accuracy) and persistence in measurement (Haryudo et al., 2019).The results of the test development show that all question items are in the valid category and have very high test reliability. This shows that the test tool prepared, if used in measuring student competence, provides reliable results with a confidence level of 95% and produces constant measurements even though they are used at different times.

The proportion of the difficulty level of the question items is part of the consideration in the preparation of the questions, namely in accordance with the normal curve that the ability so that the ability of student competence can be categorized according to the actual level of ability of the student. The multiple-choice test form provides an opportunity for test participants to guess the answers to the questions. Guessing the answer may be correct or wrong so that the final test result may not reflect the actual ability of the test taker. Therefore, a good question item must have a differentiation (discrimination index) of at least moderate. Difficulty Index (p) and discrimination Index (DI) are very useful tools for the assessment of the quality of a multiple choice. An item with known and acceptable difficulty level and Discrimination power should be preserved for future exams (Kadam et al., 2021). Question items with low differentiation must be replaced or corrected. The results of the analysis of the difference test in trial 1 showed several question items with low scores as in the validity test, namely question items no 1, 2, 5, 7, 8, 9, 10, 13, 20, 21 and 24. The results of the analysis of the difference test in the 2nd trial all test items showed that none of the questions had low or bad differentiation. Thus, the question items of the competency test are assumed to be answered based on the competency ability of the test participant, not the answer because of guessing

4. CONCLUSION

The development of competency test questions for Electrical Engineering students successfully aligns with the core competencies expected of graduates, focusing on five primary areas: electrical circuits, electric machines, distribution, transmission and distribution, and installation and illumination. Designed as multiple-choice questions targeting the higher-order cognitive levels of Bloom's taxonomy (C4, C5, and C6), the test items demonstrate robust content and empirical validity, meeting standards of item validity, difficulty, discrimination index, and reliability, making them suitable for assessing students' competencies. This study's findings suggest that such a structured

competency test could serve as a reliable tool for evaluating student readiness and may form the basis for an adaptive question bank that categorizes students by competency levels. However, the study's scope is limited to a set of predefined topics and question types, potentially overlooking some practical and emerging areas within electrical engineering. Future research should explore expanding the range of question formats, incorporating open-ended and practical assessment methods to better capture students' applied skills and adapt to evolving industry requirements.

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Conflicts of Interest: The author states that there are no personal or group interests contained in this article solely for the development of science, especially in the development of test instruments..

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