



Correlation study between the characteristics of the test items and the types of student errors in advanced calculus

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ABSTRACT

Students often repeat the same mistakes from year to year, these mistakes can come from various factors, both internal and external. Here we try to look at the external factors, one of which is the question item, whether the question is really too difficult or has low differentiation power, resulting in difficulties for students in answering it. On the other hand, we also want to know what types of errors students often experience so that we can minimize the repetition of these errors in the future. This research was conducted to see from both sides whether there was a match or not. The types of errors that are often made by students in advanced calculus courses are conceptual errors, procedural errors and operational errors. The sampling method was carried out twice, one for the sample of student error types and one for the sample of question item analysis. Here we want to know whether there is a relationship between the characteristics of the questions in the form of level of difficulty and the different strengths of the questions and the types of errors made by students in writing advanced calculus questions. From the results of the analysis of both, the results obtained were in accordance with the results, namely that although the questions tend to be moderate and relatively easy, students have not been able to maximize their learning outcomes in advanced calculus courses due to their lack of understanding at the basic level which can be seen from the types of errors such as errors in multiplication operations, errors in calculating integrals and not writing down formulas or concepts that apply in the questions. It is hoped that teachers can add small notes as a connecting thread that is broken in the concept of student understanding.

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INTRODUCTION

Education is one of humans' efforts to develop their abilities, both moral and spiritual, so that they have a personality that is in accordance with the values and culture that exist in society. This is in accordance with the National Education System Law no. 20 of 2003 Chapter I, that education is a conscious and planned effort to create a learning atmosphere and learning process so that students

actively develop their potential to have religious spiritual strength, self-control, personality, intelligence, noble character, and the skills they need, society, nation and state. Education is an effort that is carried out consciously and has been planned to create learning conditions and teaching and learning/training processes so that students can actively develop their abilities so that they have spiritual, religious, emotional strength, self-control, personality, intelligence, noble character, and the potential abilities needed (Basyirun & Roza, 2022).

There are two aspects that must be developed in the educational process, namely the individual process and the social process. Education experts prioritize how to develop all the basic abilities that children have from birth individually. Meanwhile, what is meant by social process is that education is directed at continuing to preserve and pass on cultural values to future generations (Umatin et al., 2021). The importance of education for society is illustrated by the role played by educational activities in relation to a person's development.

Education has a huge influence on the development of the lives of each individual and society through increasing intellectual abilities, emotional abilities in dealing with various things, as well as motor skills in activating and coordinating individual movements (Rahmat, 2014).

Based on this explanation, it can be said that education not only brings benefits to individuals, but also plays an important role in building a healthy, just and developing society, and is one of the main factors in creating an advanced, prosperous and sustainable civilization. Talking about education, we know that education is closely related to learning and evaluation. Through learning, students receive experiences designed to achieve educational goals. Evaluation then becomes a tool to measure the extent to which educational goals are achieved. Evaluation is one of the components that supports the educational process, and it is also one of the most significant aspects of it. Education needs evaluation as a tool or activity for controlling, ensuring, and determining educational quality (Wardani Elthia & Alawiyah, 2023). Evaluation provides feedback for learning. If the evaluation results show that the learning objectives have not been achieved, then the learning methods or educational curriculum can be adjusted or improved.

Before conducting an evaluation on students, there are several steps to distribute evaluation questions to students, namely carrying out a feasibility test on the questions that will be distributed to students. Question feasibility testing is an important step in the educational assessment process, which aims to ensure that the questions given to students can measure their abilities and understanding effectively and accurately.

In practice in the field, the feasibility test for this question has generally been carried out by teachers and lecturers. In this research, the author also wants to test the appropriateness of the exam questions given to students. The author wants to see whether the questions given to the students concerned are appropriate or not. This is done, considering the importance of testing the feasibility of questions related to assessment which ensures that the questions used can truly describe student achievement in accordance with educational objectives. This agrees with those who (Khan, 2015) explain that evaluation is an integral part of the teaching and learning process, in the evaluation process, the preparation of questions must be such that this evaluation process becomes reliable and valid.

In other words, question feasibility testing aims to ensure that the questions are effective, fair and of high quality as an assessment tool, so that they can provide an accurate picture of students' abilities and understanding in accordance with the learning objectives. If you want to generalize the feasibility test in this research, further research is needed so that you can guarantee whether this test is also valid in other places or for other levels of education. However, in general, the error lies in the students' initial knowledge and interest in certain lessons, although it is possible that errors can also occur due to the wrong form of questions or the personality of the teacher who may be too fierce or often gives punishment so that students are prone to answering incorrectly.

Another opinion, Item analysis is a process, where we use to examine response of the student to individual test items or questions to assess the quality of those items and of the test as a whole. It not only helps in improving items which will be used again in later tests, but also it can also be used to eliminate ambiguous or misleading items in a single test administration (Sahoo & Singh, 2017). item analysis is also valuable for increasing instructors' skills in test construction, and identifying specific areas of course content which need greater emphasis or clarity (Rezigalla et al., 2024; Priyani & Ekawati, 2018; Dj Pomalato et al., 2020). The subjects of the study were required to answer the questions contained in the instruments that have been prepared under the supervision of individual mathematics teacher who taught the respective class. The time allocated to answer questions was 60 minutes. The errors were analyzed using three types of errors that are conceptual errors, operational errors, and principal errors (Priyani & Ekawati, 2018).

In this study, the researcher limited the feasibility test to only conducting empirical tests, namely calculating the level of difficulty and distinguishing power. The question difficulty index is a number that shows the level of difficulty of a question, namely how easy or difficult the question is. The question difficulty index ranges from 0.00 - 1.00. To calculate the difficulty level of the questions, data is needed on the number of students who worked on the questions and the number of questions answered correctly. The greater the percentage of students who answer the question correctly, the easier the question will be. The item difficulty index is useful for selecting which items to use or retain, and which to drop.

A good question is a question that is neither too easy nor too difficult. The test question script should use questions that have a balanced level of difficulty, namely 25% difficult, 50% medium and 25% easy. The higher the question difficulty index indicates that more students answered the question correctly or in other words, the higher the question difficulty index means the question is easier (Usqo et al., 2022). What is meant by the differentiating power of the questions is how the ability of each question item can distinguish between high achieving groups from low achieving groups among the test takers, can differentiate between students who have mastered the material being tested and students who have not mastered the material being tested as shown. through a question discrimination index which we call the discrimination index where the value ranges from 0.00 to 1.00.

For a question that can be answered correctly by both intelligent and not intelligent students, then the question is not good because it has no distinguishing power. Vice versa, if students who are clever or not clever cannot answer correctly then the question is also not good because it has no differentiating power (Fatimah & Alfath, 2019). Another opinion states that multiple choice questions also require distracting choices to confuse students in choosing the right answer, what we call Distractor efficiency (DE). Distractor efficiency (DE) of multiple-choice questions (MCQs) responses is a component of the psychometric analysis used by the examiners to evaluate the distractors' credibility and functionality. The DE have impact on the difficulty and discrimination indices (Rezigalla et al., 2024).

Apart from testing the appropriateness of the questions, researchers also wanted to analyze the types of student errors. Analysis of student errors is very important in the world of education, especially in the learning and evaluation process, because it provides deep insight into students' understanding, difficulties and thinking patterns. Anyway the types of errors between students who come from different study programs or between students with varying academic abilities can be same and can be different it depend on the researcher, how he will categorize the types of errors. In this study, researchers will analyze the types of student errors in the Advanced Calculus course. Calculus courses, especially Advanced Calculus, are still often considered a frightening prospect for most students. This can be seen from the lack of enthusiasm of students before taking the Advanced Calculus lecture, many of them are skeptical about the course, this is due to their previous experience of not mastering mathematics lessons and their lack of interest in mathematics lessons. Calculus is a basic subject that is a prerequisite for other courses and is also useful in many

areas of life (Susilo et al., 2021). Even though Calculus and basic mathematics courses will always be there in whatever major they choose, so inevitably they will encounter these courses. Calculus is an essential branch of mathematics that plays a crucial role in various fields such as physics, chemistry, engineering, commerce, business, and computer science (Machisi, 2024).

As is known, Calculus is an important tool used in many fields of science and engineering. By studying calculus, students can understand various natural phenomena, create mathematical models, and solve various practical problems involving change. Considering the importance of the Advanced Calculus course, it is necessary to conduct research on student error analysis.

Often when working on Advanced Calculus questions students make the same mistakes from year to year, for this reason researchers want to analyze them directly so that they can group the types of errors that students usually make so that in the future researchers can pay more attention and special emphasis to these things. which has the potential to cause the same mistakes to students. The importance of analyzing students' mistakes in working on questions aims to find out how big the mistakes made by students and the reasons why these mistakes were made (Himmi & Husna, 2020). Yulia also explained that from mistakes made by students, the source of the error could be researched and studied further, so that the right solution could be found and the same mistake would not be repeated (Romadiastri, 2016). By knowing the location of student errors, lecturers can provide appropriate assistance to prevent students from making the same mistakes (Prafianti & Arief, 2022).

So, if a more in-depth analysis is carried out to find out the types of errors made by students when answering questions and the factors that cause these errors, it will be very effective in overcoming and finding out the causes of these errors (Faizal Amir, 2015). So, error analysis itself is the search and preparation of data about errors in working on problems made by students. This is done with predetermined data collection techniques, namely by grouping student error data based on the type of error, and then investigating its meaning (Ulfa, 2024).

In various research literature, many explain student errors in mathematics, including visual-spatial errors, comprehension errors, transformation errors, relevance errors, fact errors, procedural errors, measurement errors, presentation errors, conceptual errors, incorrect operational errors, flawed algorithms and computational errors (Rong & Mononen, 2022). In this study, the researcher focuses on conceptual errors, procedural errors and operational errors.

Conceptual errors could be classified into four which include; incorrect use of formula, misinterpreting concepts, mistyping formula and not writing equations to answer questions (Nwoke et al., 2024). The conceptual errors help the teacher to understand the students' difficulties and evaluate the level of knowledge among students, it is absolutely essential that the teacher must be aware of students' pre-conception and textbook errors (Chamundeswari, 2014). Students' conceptual errors in mathematics often occur for a variety of reasons, including a lack of basic understanding, unclear teaching, or incorrect learning habits (Najah & Jamaluddin, 2024).

Procedural error refers to errors in the process of executing algorithmic procedures, which include operations, algorithms, placements, and incorrect step, as well as missing steps in problem solving. Student lack of the basic knowledge in mathematical operations, and might have memorized formulas and properties without understanding how to apply them to problem solving (Herholdt & Sapire, 2014; Ng & Chew, 2023). Procedural errors in mathematics occur when students understand the concept but incorrectly follow the steps or procedures to solve the problem. These errors often arise due to lack of accuracy, memorisation of formulas without understanding the logic behind them, or minor errors in the application of mathematical rules.

After testing the suitability of the question items and analyzing the types of student errors, here we also want to look for the relationship between these two things by describing each relationship between the results of the question item feasibility test and the types of student errors in each question. We hope that after knowing where the imbalance in student achievement results lies, we can prevent and reduce the same mistakes, or increase efforts to improve student

achievement in the future. The novelty of our article is because we link the results of both analyzes, namely question analysis (anabut) and student error analysis, where usually other researchers only analyze one of these two analyzes.

RESEARCH METHODOLOGY

The population of this study consisted of 155 students enrolled in Advanced Calculus, divided into 4 different classes. Sampling was conducted using simple random sampling and stratified random sampling. Simple random sampling was used for item analysis, while stratified random sampling was used for student error analysis. For the item analysis sample, 44 answer sheets were taken from one randomly selected class out of the 4 existing classes. Where taking a sample of 44 students from a total population of 155 students is quite representative because it is more than 25% of the existing population. For the student error analysis sample, 15 answer sheets were randomly selected using a random number table.

The difference in sampling is done because the analysis needs are different. For item analysis where what we analyze here is the level of difficulty of the questions and the distinguishing power of the questions, then we need overall data in this case data from the same class because we will compare the number of students who answered correctly, the number of students who answered incorrectly and the number of students who did not answer. Meanwhile, for the analysis of the types of student errors, we want to see from the entire population, namely from a total population of 155, but because the average type of error is homogeneous, we decided to take random samples evenly according to their value groups by first sorting their overall values from the highest to the lowest, then we divide them into 3 classes according to the order of values, namely the upper class for one third of the data with the highest values (52 students), one third of the data with medium values (52 students) and the remaining one third of the data with the lowest values (51 students). We took random samples of $\pm 10\%$ or 5 students from each group, so the total was 15 students. Actually there are no special tools to determine the types of student errors, but for the error type criteria we can refer to several existing expert opinions (such as Watson's criteria, Polya's and others) then we adjust them to our students' answers and we create new types of criteria that are in accordance with the errors made by our students.

In the process of selecting a random sample for student error analysis, data from the 4 classes were initially combined, then sorted based on their Final Exam (UAS) scores, and then grouped into 3 different groups: upper class, middle class, and lower class. From each of these classes, 5 samples were taken, so the total sample for student error analysis was 15 student samples. In our opinion, a sample of 15 answer sheets is representative enough to describe the types of errors that occur across all groups of students, because as previously explained, these 15 answer sheets come from grouping students' scores based on their score order and have been randomly selected for each score group, especially since the average type of student error is also homogeneous. The 15 samples of data were analyzed one by one and classified based on the type of error, and then the percentage was also calculated. The item analysis conducted here was limited to the level of difficulty and discriminating power of the items, as we wanted to relate the types of errors most commonly made by students to the level of difficulty and discriminating power of the items. Here, we hope to find something that might be related to and influence student achievement.

RESULTS AND DISCUSSIONS

Based on the results of the item analysis, we can see in Table 1 below:

Table 1. Item analysis results

Item no.	Difficulty Index	Interpretation	Discrimination Index	Interpretation	Item Status
1a	0,65	Moderate item	2,33	High	Acceptable
1b	0,84	Easy item	3,11	High	Acceptable
2	0,68	Moderate item	1,82	High	Acceptable
3	0,62	Moderate item	2,95	High	Acceptable
4	0,65	Moderate item	2,71	High	Acceptable
5	0,39	Moderate item	4,65	High	Acceptable

These results were obtained from a sample of 44 students from one selected class out of four classes in the population. Based on the analysis, there should be no difficulty level for the items since the analysis shows that, based on the difficulty index, each item is categorized as moderate (with a difficulty index of $0.25 < x < 0.75$) and easy (with a difficulty index above 0.75) so the items are still in the good category. Similarly, the discrimination index results have a very good interpretation, meaning that all or each item has a high discrimination index, which means that each item given can describe the diversity of student understanding.

Therefore, based on the results of the item analysis, it can be concluded that all items are in the good category. Meanwhile, based on the analysis of student errors that has been conducted, the data on student errors in Advanced Calculus is presented in Table 2 below

Table 2. Percentage of subject student answers in solving differential equation questions

Category	Question Number					
	1a	1b	2	3	4	5
Correct Answer (%)	33,33	66,67	26,67	0	0	0
Wrong Answer (%)	46,67	20	73,33	86,67	86,67	66,67
Didn't Answer (%)	20	13,33	0	13,33	13,33	33,33

In Table 2. It can be seen that students who answered correctly in question no.1a were 33.33%, those who answered incorrectly were 46.67% and those who did not answer were 20%. Furthermore, in question no.1b, students who answered the question correctly were 66.67%, who answered incorrectly by 20% and did not answer by 13.33%. Then in question no.2, many students answered incorrectly, namely 73.33% and those who answered correctly by 26.67%, but there were no students who did not answer the question. Next for questions no.3, 4 and 5 have the same percentage, namely students who answered incorrectly by 86.67%, who did not answer by 13.33%, and no one answered the question correctly. Based on the results of the analysis, it can be concluded from each question that more than 50% of students answered the questions incorrectly, except for question no.2. Then student errors in answering questions are also analyzed based on the types of errors, namely conceptual errors, principle/procedural errors, and operational errors. The following are the results of the analysis of the types of student errors contained in table 3.

Table 3. Types of student mistakes in solving differential equation problems in courses advanced calculus

No	Question	Types of Errors		
		Conceptual Errors	Principle Error	Operation Errors
1a	Define the following solution of a separate variable differential equation $xy \frac{dy}{dx} = -\frac{2x^2 + 1}{3y + 1}$	Wrong in not writing formulas, theorems or definitions to answer problems	Wrong in cross-multiplying	Error in the calculation of integral operations
1b	Define the following solution of a separate variable differential equation $24yy' + 8x = 0$	Wrong in not writing formulas, theorems or definitions to answer problems	Wrong in cross-multiplying	Error in the calculation of integral operations

2	Determine the exact differential equation solution of $\frac{dy}{dx} = -\frac{3x+4y}{4x+4y}$ with $y(0) = 5$	Wrong in not writing down the exact differential equation formula	Wrong because it does not pay attention to the prerequisites in using the formulas applied in calculating exact differential equations	Wrong in performing non-hierarchical steps in completion, Wrong in the calculation of integral operations
3	Look for a solution to the linear differential equation $x^2 \frac{dy}{dx} - x^2 y = 10x$	Wrong in not writing down the formula for linear differential equations	Wrong because it does not pay attention to the pre-conditions in using the formulas applied in calculating linear differential equations	Wrong in performing non-hierarchical steps in completion, Wrong in the calculation of integral operations
4	Solve homogeneous differential equations $\frac{dy}{dx} = \frac{x+6y}{5x}$	Mistake in not writing down the formula of homogeneous differential equations	It is wrong because it does not pay attention to the pre-conditions in using the formulas applied in calculating homogeneous differential equations	Wrong in performing non-hierarchical steps in completion, Wrong in the calculation of integral operations
5	Define a solution to an exact non-differential equation $(3x^2y^2)dx + (4x^3y - 12)dy = 0$	Wrong in not writing down the differential equation formula is not exact	Wrong because it does not pay attention to the prerequisites in using the formulas applied in calculating differential equations are not exact	Wrong in performing non-hierarchical steps in completion, Wrong in the calculation of integral operations

From table 3 above, the types of conceptual errors, principles and operations, are discussed further, as follows.

1. Conceptual Errors, conceptual errors that often appear on student answer sheets are mistakes in not writing formulas, which are related to questions to answer problems. From the results of the analysis, it was found that an average of 33.33% of students were wrong in applying the concept of separate variable differential equations, linear differential equations, homogeneous differential equations, exact and non-exact differential equations. This can be seen from some students who still have problems in applying the differential equation formula determined by the question, and there are even some who do not answer the question.
2. Principle/ Procedural Errors, principle/Procedural errors appear on the student's answer sheet, which is wrong because they do not pay attention to the pre-requirements in using formulas, which are related to questions to answer problems. From the results of the analysis, it was found that on average 46.67% of students were wrong in paying attention to the pre-requirements in using the formula of separate variable differential equations, linear differential equations, homogeneous differential equations, exact and non-exact differential equations. This can be seen from some students who are incomplete in the formula of homogeneous differential equations (with analogies $z = \frac{y}{x}$), then in the problem of linear differential equations students are wrong in determining the value. $\int p(x)dx$
3. Operation Errors, operation Errors are the most frequent mistakes made by students when answering questions. From the results of data analysis, it was found that an average of 78.89% of students were wrong in the steps in solving problems that are integral concept operations, even some students were incomplete in completing the answers, such as questions number 3, 4, and 5. In the width of the students' answers, several cases of operational errors were found, including questions no. 1a and 1b in separate variable differential equations, there were some students who made mistakes in cross-multiplying the two left and right equations. Furthermore, in question number 2 regarding exact differential equations, it was also found that

some of the students still did not understand the operation of derivatives on variables x and y variables so that they could not determine whether the differential equation was exact or non-exact. In question no. 3 regarding linear differential equations, the common mistake is that many do not understand the value $\mu(x) = e^{\int p(x)dx}$ and integral operation. In question number 4 regarding homogeneous differential equations, students make many mistakes in performing non-hierarchical steps such as students calculating the value of $\frac{x}{5x}$ the result equal to 5, the result should be. Another mistake that was found was that there were students who calculated the results equal to, should be. In question number 5 regarding non-exact differential equations, many students do not complete the answer, on average only until determining whether the equation is exact or non-exact, then students have not been able to enforce non-exact differential equations $\frac{1}{5}z - z\frac{6}{55}$.

Based on the discussion above, it can be concluded that students make the most mistakes in operating errors, which is around 78.89%. This is due to the lack of understanding of basic mathematical concepts of students, so that many students experience mistakes in solving problems, especially in integral calculations. Integral material is one of the prerequisite materials that must be understood by students to learn differential equation material. So, if students are weak in the basic concept of integrals, then they will have difficulty and experience mistakes in solving differential equations. Therefore, in order to prevent the same mistakes from happening again, the basic concepts of students must be strong, such as inequality, derivative and integral material. One of the efforts that can be made to improve the basic concepts of students is to construct student knowledge and provide sufficient practice. More home assignments must be given to the pupils and periodical checking and diagnosis of the understanding of the concepts immediately after the teaching, may reduce more errors (Chamundeswari, 2014).

If we connect the percentage of errors and the results of the analysis of the existing question items, then for the error rate of question number 3 and 4 has a fairly high percentage of errors, which is 86.67% and the percentage of not answering is 13.33%, while the percentage of correct answers is 0%, even though the results of the analysis of question items for the difficulty index are obtained results of 0.62 and 0.65 which have an interpretation that the question is classified as a medium question and even tends to be easy because of the index relatively high near the limit of 0.75. From here, it can be seen that there is an imbalance between the level of difficulty of the question and the number of students who answer incorrectly or the large percentage of students who answer incorrectly, but it makes sense if we look at the type of student error in numbers 3 and 4, namely "Wrong in not writing the formula for linear and homogeneous differential equations, Wrong because it does not pay attention to the prerequisites in using the formulas applied in calculating differential equations linear and homogeneous, as well as erroneous in performing non-hierarchical steps in solving and erroneous in the calculation of integral operations." Students look confused in answering questions number 3 and 4 so they only answer simply with many shortcomings here and there.

As for question number 1b which has the highest difficulty index, aka the easiest question, it turns out that it does have the highest percentage of answering the question correctly, which is 66.67% and the smallest percentage of wrong answers, which is 20%, here the type of student error is only wrong in not writing down formulas, theorems or definitions to answer problems, wrong in cross-multiplying, and incorrect in the calculation of integral operations. So this is a fundamental type of error that explains the skill level of the student. What is interesting here is question number 5 which has a fairly low difficulty index but is still in the medium question category, which is 0.39 and a high difference or 4.65. From this, it can be seen that the questions in the category are very good because they have a moderate level of difficulty, the questions tend to be difficult so that they can distinguish students' abilities well, which can be seen from the high index of question differentiation.

From the table of types of student errors, it can also be seen that the explanation that causes it all is wrong in not writing down the formula of the differential equation is not exact, wrong because it does not pay attention to the prerequisites in using the formulas applied in calculating the differential equation is not exact, it is wrong in performing steps that are not hierarchical in solving, and wrong in the calculation of integral operations.

From the various descriptions above, it can be seen that actually the questions are very suitable to be used here because they are qualified for the level of difficulty and differentiation of the questions, judging from the results of the types of errors that exist seem to be related to the ability of previous students, especially basic things such as the concept of multiplication and simple integrals or other basic concepts as well as students' previous knowledge so that students experience difficulties in learning, this is also often caused by the lack of interest and skills of students in mathematics so that they become ignorant of things that smell mathematics.

As a suggestion from the author, perhaps lecturers or teachers can provide additional notes either directly or indirectly about basic materials that can be a link and support students in understanding the materials in advanced calculus so that they can reconnect the common thread that had been cut off in the understanding of students who take this course, for example giving a kind of footnote or in the form of YouTube link references and so on. what we mean here is just additional introductory material that can be inserted during learning that can help remember or inform about small notes about introductory material related to the material being discussed and studied at that time. This is expected to be a common thread that connects new material with previous material related to the material. The addition can be in the form of a direct explanation, appropriate video links or in the form of small notes. The teaching methods that have been used are actually quite good, it just needs to be added to a little introduction to the material, if we look at the types of errors made by students, namely those related to initial concepts or previous student knowledge, so that students have difficulty in learning new material.

CONCLUSION

The results of the analysis of the question items showed that the question items were in the category of relatively medium and easy and had a high question differentiation so that there was no reason for students not to solve all the questions, but it turned out that there were still many students who made mistakes, both conceptual, procedural and operational errors. Our suggestion may be that further research of the same kind can be carried out by adding a little treatment in the form of additional notes of supporting materials and additional special exercises to improve students' skills in advanced calculus material.

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