

Analysis of Student Errors in Solving Non Homogeneous Differential Equations Problems Based on Kastolan Stages

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ABSTRACT

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The purpose of this study is to identify and classify any errors made by students in solving problems of non-homogeneous order n differential equations and to find out what causes students to make errors in solving problems. This research is a qualitative descriptive research. The instruments used in this study were the Mathematical Ability Test, the Differential Equation Problem Solving Test and interview guidelines. The selection of subjects began by giving a math ability test to 35 students in the class. From the results of these tests, 3 students were then selected from a variety of errors to become research subjects. The criteria for selecting research subjects refer to: (a) the number of mistakes made by students in answering test questions; (b) variations in the types of errors made by students; (c) have the ability to communicate both orally and in writing; (d) willing to be interviewed. Based on the results of the study, information was obtained that the types of student errors in solving non-homogeneous order n differential equations based on the Kastolan stages were: (1) conceptual errors consisted of errors in the use of formulas in answering questions and using formulas that were not in accordance with the conditions or prerequisites for enactment formulas, (2) procedural errors consist of errors because they cannot solve the problem in the simplest form and errors because they cannot continue the completion step, (3) technical errors consist of errors in calculating the value of an arithmetic operation, errors in writing that there is constant or variable written wrong or forgot not to write or an error moving a constant or variable from one step to the next, and improperly substituting values into variables. While the factors that cause student errors in solving problems of non-homogeneous order n differential equations are students who do not understand the prerequisite materials needed to solve problems of non-homogeneous order n differential equations, do not understand the concept of determining the general form of a special solution with certain prerequisites, student skills in carrying out arithmetic operations they are still lacking, less thorough, in a hurry, and nervous so that there are several completion steps that are miscalculated, missed, not written down, and not converted to the simplest form.



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A. INTRODUCTION

Differential Equation is an equation that states the relationship of an unknown function and its derivatives (Nuryadi, 2018). This differential equation has an important role and is widely applied in various fields of science such as science, engineering, ecology, economics and other sciences (Oktavia & Khotimah, 2016; Sihombing & Dahlia, 2018). Meanwhile, in university level, this differential equation is one of the advanced calculus courses, both basic calculus and advanced calculus. For this reason, studying the material for differential equations requires prerequisite material, especially derivatives and integrals which have been discussed in the calculus course.

The materials studied in the differential equations course are: introduction to differential equations, ordinary differential equations of order 1, differential equations of order n ($n > 1$ and linear), and systems of differential equations (simultaneous differential equations). From some of these materials, the material that is very difficult for students to understand is order n differential equations, especially for non-homogeneous order n differential equations. This is based on the experience of the researcher as a lecturer in differential equations that the student learning outcomes in each class on the material are very low when compared to learning outcomes in other materials. During lectures, students also seemed confused in working on non-homogeneous order n differential equations. From the results of interviews with several students who have taught differential equations courses, they also stated the same thing that they had difficulties in solving problems of non-homogeneous order n differential equations, in addition to the complex completion steps, they also required calculating skills and understanding concepts in the material. previous prerequisites.

Differences in calculation skills and student abilities on prerequisite material can cause many errors to occur when solving non-homogeneous order n differential equations. Cause of student errors in solving differential equations in general is because students do not optimize the initial knowledge they already have (Sulistiyorini, 2017). Beside that, the mistakes that many students make in solving non-homogeneous differential equations are errors in basic concepts and lack of knowledge of prerequisite material (Khusniah, 2014). Meanwhile, according to another researcher suggests that errors in solving differential equations include errors in performing arithmetic operations, errors in performing the first and second derivatives (Naisunis et al., 2018). Based on some of the results of these studies, we can know that there are various causes for students to make mistakes in solving differential equations, especially in non-homogeneous order differential equations.

Over time, many studies have discussed the analysis of student errors in mathematics learning (Dj Pomalato et al., 2020; Haerani et al., 2021; Mauliandri & Kartini, 2020; Priyani & Ekawati, 2018; Riantini W. et al., 2020). Error analysis is a study of students' work errors to find an explanation of the reasons for these errors (Herholdt & Sapire, 2014). This error analysis is related to students' errors due to lack of conceptual and procedural understanding (Ketterlin-Geller & Yovanoff, 2009).

Some experts also have classified the types of errors. Kastolan distinguishes three types of errors, namely conceptual errors, procedural errors, and technical errors (D et al., 2021). Watson divides errors into 8 categories, namely: inappropriate (id), inappropriate procedure (ip), omitted data (od), omitted conclusion (oc), response level conflict (rlc), undirected manipulation (um), skills hierarchy problem (shp), apart from the seven categories above (ao) (Evriyanti et al., 2020). Meanwhile Newman divides errors, namely reading errors, comprehension errors, transformation errors, process skill errors (Fitriani et al., 2018). From the three expert opinions above, the researcher uses the types of errors according to Kastolan because the criteria used are simpler and include the criteria for the types of errors expressed by Watson and Newman. As for in detail, the types of errors and indicators used in this study can be seen in Table 1 below.

Table 1. Types and Indicators of Errors According to Kastolan

Types of Error	Indicator
Conceptual Error	<ol style="list-style-type: none"> 1. Error in the use of formulas in answering questions 2. Using a formula that is not in accordance with the conditions or prerequisites for the application of the formula
Procedural Error	<ol style="list-style-type: none"> 1. Irregularity of problem solving steps 2. Can't solve the problem in the simplest form 3. Error due to not being able to proceed with the completion step
Technical Error	<ol style="list-style-type: none"> 1. Error in calculating the value of an arithmetic operation 2. Error in writing, namely there are constants or variables that are written wrong or missed or errors move constants or variables from one step to the next 3. Improper in substituting values into variables

Based on the description above, to minimize repeated errors and to improve the quality of learning in the classroom so as to improve student learning outcomes on non-homogeneous order n differential equations, a study is needed that discusses errors that are often made by students. So the title of this study is the analysis of student errors in solving non-homogeneous differential equations based on the Kastolan stages. The aim of this research are: (1) to describe the types of student errors in solving non-homogeneous order n differential equations, (2) to describe the factors that cause students to make mistakes in solving non-homogeneous order n differential equations. In this study, the researcher limits the problem of solving a non-homogeneous second-order differential equation with $f(x)$ in the form of a polynomial function by using a solution method in the form of an indeterminate coefficient method.

B. METHODS

This research is included in descriptive research with a qualitative approach. Descriptive research is a research method that describes a phenomenon and its characteristics (Nassaji, 2015). While the qualitative research method is a research method used to examine the condition of natural objects, where the researcher is the key instrument, the data analyzed is in the form of verbal descriptions that are poured into field notes which include several steps such as coding, comparison, integration, triangulation, and interpretation (Aini et al., 2017; Atmowardoyo, 2018).

The instruments used in this study were the Mathematical Ability Test (MAT) to determine the research subject, the Differential Equation Problem Solving Test (DEPST) and interview guidelines. Before being used, the three instruments were validated by the validator. The subjects in this study were students in the fourth semester of the mathematics education study program, faculty of teacher training and education, University of Madura. The selection of subjects began by giving a math ability test to 35 students in the class. From the results of these tests, 3 students were then selected from a variety of errors to become research subjects. The criteria for selecting research subjects refer to: (a) the number of mistakes made by students in answering test questions; (b) variations in the types of errors made by students; (c) have the ability to communicate both orally and in writing; (d) willing to be interviewed.

The technique used to collect data in this study is to perform a Differential Equation Problem Solving test (DEPST) and interviews. The test used in this study is a description test in the form of non-homogeneous n order differential equations (limited to non-homogeneous second-order differential equations). The function of this test is as a tool to identify the

location of errors made by students. After the data obtained from the test results, then conducted interviews with students as research subjects. Researchers chose 3 students as research subjects in accordance with the criteria for selecting research subjects. The purpose of this interview is to find out as many things as possible related to the location of student errors in solving non-homogeneous n order differential equations.

To check the validity of the data from the problem-solving tests and interviews in this study, triangulation was carried out. In this study the researchers used time triangulation, where data validation in this study was carried out by comparing the results of test and task-based interviews from Test Instrument 1 with test and task-based interviews from Test Instruments 2 (equivalent to the first question) at different times. If the same trend is obtained, then data collection on the subject has been completed and conclusions can be drawn. However, if the data from test and task-based interview results from Test Instrument 1 and Test Instrument 2 show different tendencies, then a test and task-based interview from Test Instrument 3 (equivalent to the first and second questions) is conducted. If from the comparison of the data, all the trend data are still different, then it is done again and again until valid data is obtained. Data or information is said to be valid if there is consistency, similarity of views, opinions or thoughts on the results of test and task-based interviews that have been carried out by researchers.

Data analysis was carried out after data collection. The data analysis in the field in this study using the Miles and Huberman (1992) model are as follows: 1) Data reduction, at this stage the researcher examines the work of students, records and compiles the results of interviews by playing back the recording of the interview process so as to obtain the required information, selecting data obtained for each subject in accordance with the required information which in this case is about student errors, then triangulates the results of the first test and interview with the results of the second test and interview in order to validate the qualitative data; 2) Data Presentation, at this stage the researcher performs the process of presenting data about student errors in solving non-homogeneous n order differential equations obtained from test results and interviews with selected subjects. In this case the researcher presents the data in descriptive form, which is described on the aspects that are assessed and observed during the research activities; 3) Conclusion Drawing, at this stage the researcher summarizes the data and checks the correctness of the data. The data obtained will be concluded in accordance with the purpose of the study, which is to describe the errors of the research subject. Systematically, the research procedure is shown in Figure 1 below.

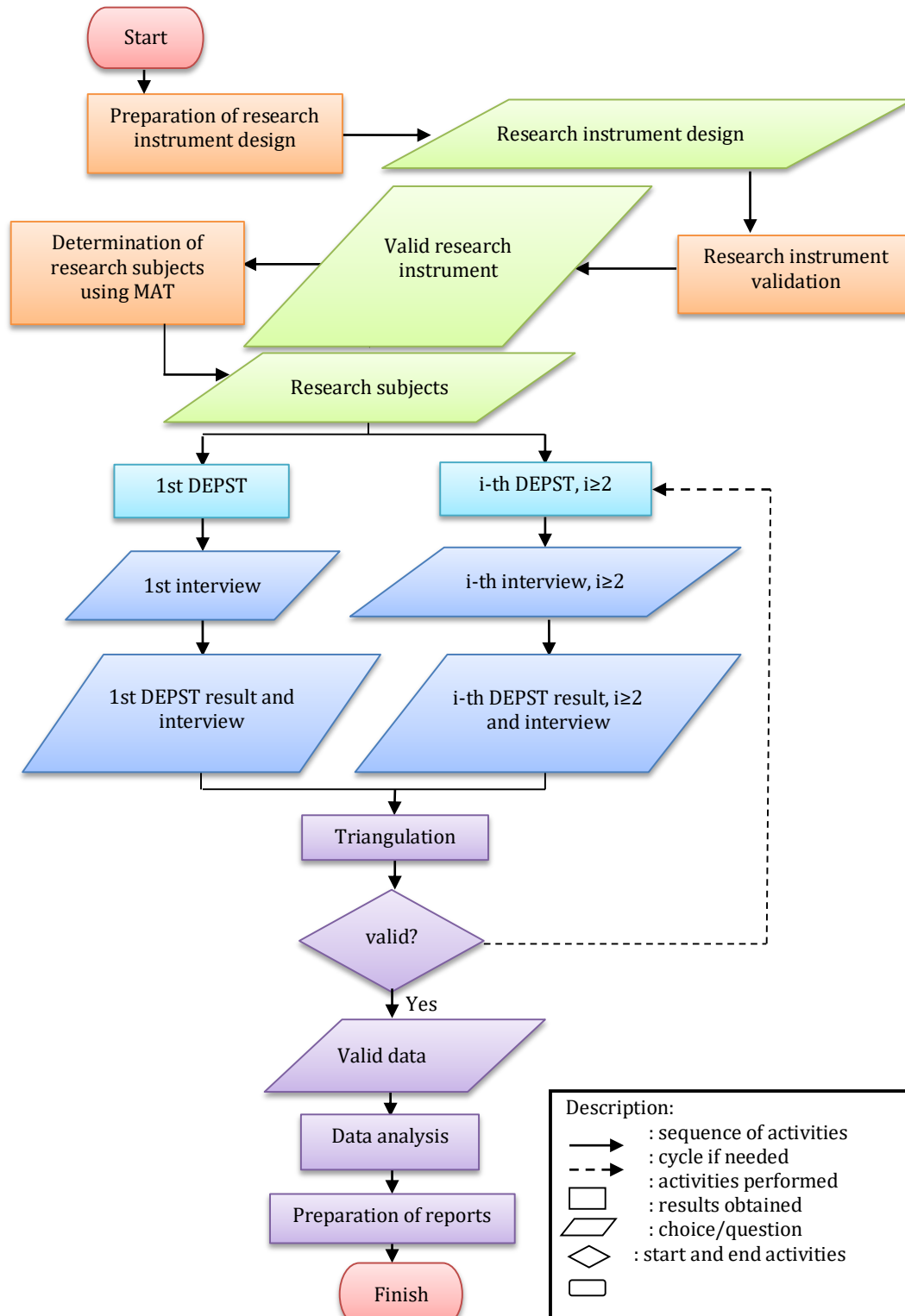


Figure 1. Research Procedure Flowchart

C. RESULT AND DISCUSSION

The following is a summary of the data about the type of subject error in solving Non-homogeneous differential equation problem based on Kastolan stages.

Table 2. Summary of the Types of Subject Errors

Types of Error	Indicator	Subject		
		S1	S2	S3
Conceptual Error	1. Error in the use of formulas in answering questions	√	√	√
	2. Using a formula that is not in accordance with the conditions or prerequisites for the application of the formula	√	√	√
Procedural Error	1. Irregularity of problem solving steps			
	2. Can't solve the problem in the simplest form		√	√
	3. Error due to not being able to proceed with the completion step	√	√	
Technical Error	1. Error in calculating the value of an arithmetic operation	√		√
	2. Error in writing, namely there are constants or variables that are written wrong or missed or errors move constants or variables from one step to the next	√	√	√
	3. Improper in substituting values into variables		√	

Description: S1 = first subject, S2 = second subject, S3 = third subject

The details of the types of errors and the factors that cause errors made by each subject in solving the problem of non-homogeneous differential equations based on the Kastolan stages are as follows:

1. First Subject (S1)

The following is the answer to the first subject (S1) in solving the problem of non-homogeneous order n differential equations.

$y'' - 13y' = 26x$
 Anggap $f(x) = 0$
 maka pers karakteristiknya
 $r^2 - 13r = 0$
 $r^2 - 13r = 0 \Rightarrow a = 1, b = 0, c = -13$
 $r_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
 $= \frac{-0 \pm \sqrt{0^2 - 4 \cdot 1 \cdot (-13)}}{2 \cdot 1}$
 $= \frac{-0 \pm \sqrt{0 - 52}}{2}$
 $= \frac{-0 \pm \sqrt{-52}}{2}$
 $= \frac{0 \pm 26i}{2}$
 $= 0 \pm 13i$

karena $f(x) = 26x$ berupa fungsi eksponensial
 dg $\alpha = 26$ sedangkan $r = \alpha = 26$ merupakan akar persamaan karakteristika PD homogen
 kalipatan $2 (p = 2)$ maka
 $y_k = x^p (ce^{\alpha x}) = x^2 (ce^{26x})$
 karena disoal turunan teringginya u/turu
 nan kedua, maka turunkan y_k dua kali

Consider $f(x) = 0$
 Then the characteristic equation:
 $r^2 - 13r = 0$
 $r^2 - 13r = 0 \rightarrow a = 1, b = 0, c = -13$
 $r_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
 $= \frac{-0 \pm \sqrt{0^2 - 4 \cdot 1 \cdot (-13)}}{2 \cdot 1}$
 $= \frac{-0 \pm \sqrt{0 - 52}}{2}$
 $= \frac{-0 \pm \sqrt{-52}}{2}$
 $= \frac{0 \pm 26i}{2}$
 $= 0 \pm 13i$

because $f(x) = 26x$ is an exponential function with $\alpha = 26$ while $r = \alpha = 26$ is the root of the characteristic equation of a homogeneous differential equation multiple of 2 ($p = 2$) then $y_k = x^p (ce^{\alpha x}) = x^2 (ce^{26x})$ because in the problem the highest derivative is the second derivative, then lower y_k twice

Description: Conceptual error Procedural error Technical error

Figure 2. The Steps for Solving the First Subject (S1) in Answering Questions

Based on S1's answer sheet, it is clear that several errors were made by the first subject (S1). First, there are two types of conceptual errors, namely (1) error in the use of formulas in answering questions because in determining the general form of a special solution (y_k), S1 using the exponential form ce^{ax} should use the polynomial form $A_1x + A_0$ and (2) using a formula that is not in accordance with the conditions or prerequisites for the application of the formula because in determining the general form of a special solution (y_k), S1 multiplies x^p by ce^{ax} where $p = 2$ should multiply x^p by $A_1x + A_0$ where $p = 1$, so the correct general form of a special solution (y_k) is $x^p(A_1x + A_0) = x^1(A_1x + A_0) = A_1x^2 + A_0x$. Second, procedural errors are errors because due to not being able to proceed with the completion step. Third, there are two types of technical errors, namely (1) errors in calculating the value of an arithmetic operation because in the third step the use of the abc formula to find the roots of the characteristic equation S1 miscalculated $\frac{-0 \pm \sqrt{0^2 - 4 \cdot 1 \cdot (-13)}}{2 \cdot 1} = \frac{-0 \pm \sqrt{0-52}}{2}$ should be $\frac{-0 \pm \sqrt{0+52}}{2}$ and in the next step $\frac{-0 \pm \sqrt{0-52}}{2} = \frac{0 \pm 26i}{2}$ is clearly wrong because $\sqrt{52}$ is not 26, then (2) errors in writing are missing constants or variables, this can be seen when the characteristic equation $r^2 - 13r = 0$ there is a missing variable r so that it becomes $r^2 - 13 = 0$. As for the factors causing the error that the first subject (S1) made in solving the problem of non-homogeneous differential equations, namely not understanding the concept of determining the general form of a special solution (y_k) with certain prerequisites, was less thorough and rushed so that there were some miscalculated solution steps.

2. Second Subject (S2)

The following is the answer to the second subject (S2) in solving the problem of non-homogeneous order n differential equations.

<p>solusi homogen = (y_h) pers. karakteristik = $r^2 - 13r = 0 \rightarrow a = 1, b = (-13), c = 0$ Rumus ABC = $\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $= \frac{-(-13) \pm \sqrt{(-13)^2 - 4 \cdot 1 \cdot (0)}}{2 \cdot 1}$ $= \frac{13 \pm \sqrt{169 - 0}}{2}$ $= \frac{13 \pm 13}{2} \left\{ \begin{array}{l} \frac{13+13}{2} = \frac{26}{2} = 13 \\ \frac{13-13}{2} = 0 \end{array} \right\} \text{berbeda}$ <div style="border: 1px solid blue; padding: 2px; display: inline-block;">$y_h = C_1 e^{13x} + C_2 e^{0x}$</div> solusi khusus = (y_k) $r = 0$ bukan akar dan persamaan karakteristik PD homogen $f(x) = 26x$ <div style="border: 1px solid red; padding: 2px; display: inline-block;">$y_k = A_2 x^2 + A_1 x + A_0$</div> <div style="border: 1px solid red; padding: 2px; display: inline-block;">$y_k' = 2A_2 + A_1$</div> $y_k'' = 2A_2$ substitusikan ke soal $y'' - 13y' = 26x$ $2A_2 - 13(A_2 x^2 + A_1 x + A_0) = 26x$ $2A_2 - 13A_2 x^2 + 13A_1 x = 26x$ </p>	<ul style="list-style-type: none"> Homogeneous solution = (y_h) the characteristic equation: $r^2 - 13r = 0 \rightarrow a = 1, b = -13, c = 0$ $r_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $= \frac{-(-13) \pm \sqrt{(-13)^2 - 4 \cdot 1 \cdot (0)}}{2 \cdot 1}$ $= \frac{13 \pm \sqrt{169 - 0}}{2}$ $= \frac{13 \pm 13}{2} \left\{ \begin{array}{l} \frac{13+13}{2} = \frac{26}{2} = 13 \\ \frac{13-13}{2} = 0 \end{array} \right\} \text{different}$ $y_h = c_1 e^{13x} + c_2 e^{0x}$ Custom solution = (y_k) $r = 0$ is not the root of the characteristic equation of a homogeneous differential equation. $f(x) = 26x$ $y_k = A_2 x^2 + A_1 x + A_0$ $y_k' = 2A_2 + A_1$ $y_k'' = 2A_2$ Substitute for question $y'' - 13y' = 26x$ $2A_2 - 13(A_2 x^2 + A_1 x + A_0) = 26x$ $2A_2 - 13A_2 x^2 + 13A_1 x = 26x$
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Description: Conceptual error Procedural error Technical error

Figure 3. The Steps for Solving the Second Subject (S2) in Answering Questions

Based on S2's answer sheet, it is clear that several errors were made by the second subject (S2). First, there are two types of conceptual errors, namely (1) errors in use formulas in answering questions because in determining the first derivative of a special solution (y_k') it should be wrong $2A_2x + A_1$ instead of $2A_2 + A_1$ and (2) Using a formula that is not in accordance with the conditions or prerequisites for the application of the formula because in determining the general form of the special solution (y_k), S2 does not multiply x^p by $A_1x + A_0$ where $p = 1$, because it is based on the known prerequisites in the problem that $f(x) = 26x$ is a polynomial function of degree 1 and there is $r = 0$ as much as 1 time ($p = 1$) at the root of the characteristic equation in a homogeneous solution, so that the correct general form of a special solution (y_k) is $x^p(A_1x + A_0) = x^1(A_1x + A_0) = A_1x^2 + A_0x$. Second, there are two types of procedural errors, namely (1) can't solve the problem in the simplest form because the second subject (S2) cannot express a homogeneous solution (y_h) to the simplest form, namely $y_h = c_1e^{13x} + c_2e^{0x}$ can be simplified to $y_h = c_1e^{13x} + c_2$ and (2) Error due to not being able to proceed with the completion step. Third, there are two types of technical errors, namely (1) errors in writing, namely there are constants or variables that are written wrong or missed or errors in move constants or variables from one step to the next, this can be seen in the third step when substituting y_k, y_k', y_k'' to the question, something was missed and it was written incorrectly in the use of positive and negative signs resulting from the substitution, namely $2A_2 - 13A_2x^2 + 13A_0 = 26x$ should be $2A_2 - 13A_2x^2 - 13A_1x - 13A_0 = 26$, furthermore (2) improper in substituting values into variables, this can be seen in the second step when substituting y_k, y_k', y_k'' into the problem, what should be substituted is $y_k' = 2A_2 + A_1$ instead of y' and not $y_k = A_2x^2 + A_1x + A_0$.

As for the factors causing the error that the second subject (S2) made in solving the problem of non-homogeneous differential equations, namely not understanding the prerequisite material, namely the derivative concept, did not understand the concept of determining the general form of a special solution (y_k) with certain prerequisites, skills in performing arithmetic operations are still lacking, less thorough and in a hurry so that there are several completion steps that are miscalculated, missed, not written, and not converted to the simplest form.

3. Third Subject (S3)

The following is the answer to the third subject (S3) in solving the problem of non-homogeneous order n differential equations.

$8,5\sqrt{10}$ dan $4,5\sqrt{10}$ then the homogeneous solution is $y_h = c_1 e^{8,5\sqrt{10}x} + c_2 e^{4,5\sqrt{10}x}$ not $y_h = c_1 e^{8,5\sqrt{10}} + c_2 e^{4,5\sqrt{10}}$ and (2) using a formula that is not in accordance with the conditions or prerequisites for the application of the formula because in determining the general form of a special solution (y_k), S3 does not multiply x^p by $A_1x + A_0$ where $p = 1$, because based on the known prerequisites in the problem that $f(x) = 26x$ is a polynomial function of degree 1 and there is $r = 0$ as much as 1 time ($p = 1$) at the root of the characteristic equation in a homogeneous solution, so that the general form of a special solution (y_k) is true is $x^p(A_1x + A_0) = x^1(A_1x + A_0) = A_1x^2 + A_0x$ not $A_2x^2 + A_1x$. Second, procedural error is can't solve the problem in the simplest form because the third subject (S3) has not stated the general solution (y) to the simplest form, namely $y = c_1 e^{8,5\sqrt{10}} + c_2 e^{4,5\sqrt{10}} - 1x^2$ can be simplified to $= c_1 e^{8,5\sqrt{10}} + c_2 e^{4,5\sqrt{10}} - x^2$. Third, there are two types of technical errors, namely (1) errors in calculating the value of an arithmetic operation, this can be seen in the third, fourth and fifth steps in determining the roots of the characteristic equation using the abc formula, $\frac{13 \pm \sqrt{169-4}}{2}$ should be wrong $\frac{13 \pm \sqrt{169-0}}{2}$, then $\frac{13 \pm \sqrt{160}}{2}$ should be wrong $\frac{13 \pm \sqrt{165}}{2}$, and $\frac{17\sqrt{10}}{2}$ and $\frac{9\sqrt{10}}{2}$ is wrong, it should remain as it was in its original form, it can no longer be operated, that is, it remains $\frac{13+4\sqrt{10}}{2}$ and $\frac{13-4\sqrt{10}}{2}$, then (2) errors in writing, namely there are constants or variables that are written wrong or missed, this can be seen in the third and fourth steps when substituting y_k, y_k', y_k'' into the problem that is $2A_2 - 13 2A_2 + 13A_1 = 26x$ should be $2A_2 - 13 2A_2x - 13A_1 = 26x$ and $13 2A_2 + 13A_1 = 26x$ should be $-13A_2x + (2A_2 - 13A_1) = 26x$.

As for the factors causing the error that the third subject (S3) made in solving the problem of non-homogeneous differential equations, namely not understanding the prerequisite material, namely the concept of determining a general solution from a homogeneous solution, did not understand the concept of determining the general form of a special solution (y_k) with certain prerequisites, skills in performing arithmetic operations are still lacking, less thorough, in a hurry, and nervous so that there are several completion steps that are miscalculated, missed, not written, and not converted to the simplest form.

Based on the data from the three research subjects above, information was obtained that the types of student errors in solving non-homogeneous order n differential equations were based on the Kastolan stages as follows.

- a. Conceptual errors consist of two types, namely (a) errors in use of formulas in answering questions such as errors in determining homogeneous solutions (y_h), errors in determining the general form of a special solution (y_k), and errors in determining the first derivative of a special solution (y_k'); (b) Using a formula that is not in accordance with the conditions or prerequisites for the application of the formula, such as an error in determining the general form of a special solution (y_k) that does not comply with the prerequisites for the function $f(x)$ known in the problem and the roots of the characteristic equation obtained in homogeneous solution (y_h). This is strengthened from the results of previous research. The types of errors found when students solve inhomogeneous differential equations using the indeterminate coefficient method are errors in the formation of general solutions of homogeneous differential equations and special solutions of inhomogeneous differential equations (Khusniah, 2014). Beside that, several types of student errors in solving ordinary differential equations are errors in determining derivatives because they do not understand the prerequisite course material, namely calculus II on derivative functions and errors in determining characteristic equations because they cannot determine characteristic equations (Budiyono & Guspriati, 2009). Other difficulties of students in

- solving non-homogeneous second-order differential equations is in determining a special solution that is not homogeneous because it is caused by an initial error in determining the characteristic equation (Ningsih & Mulbasari, 2019).
- b. Procedural errors consist of two types, namely (a) Can't solve the problem in the simplest form such as not stating a homogeneous solution (y_h) and general solution (y) in the simplest form; (b) error due to not being able to proceed with the completion step. Based on the results of previous research that 35.29% of students' errors in solving inhomogeneous differential equations are because they do not finish working (Khusniah, 2014).
 - c. Technical errors consist of three types, namely (a) errors in calculating the value of an arithmetic operation such as calculating errors in using the abc formula to find the roots of characteristic equations; (b) errors in writing, namely there are constants or variables that are written wrong or missed or errors move constants or variables from one step to the next such as there is a variable r that is not written when determining the characteristic equation and there are some terms that are not written when substituting y_k, y'_k, y''_k to the questions, as well as typos in the use of positive and negative signs; and (c) improper in substituting values into variables such as incorrectly substituting the first derivative of a special solution (y'_k) with y_k instead of y'_k . The types of errors found when students solve inhomogeneous differential equations include errors in the formation of characteristic equations by 75% and errors in calculations by 25% (Khusniah, 2014).

While the factors that cause student errors in solving problems of non-homogeneous order n differential equations are students who do not understand the prerequisite materials needed to solve problems of non-homogeneous order n differential equations, namely the concept of derivatives and general solutions of homogeneous differential equations, students also do not understand the concept determine the general form of a special solution (y_k) with certain prerequisites, students' skills in performing arithmetic operations are still lacking, less thorough, in a hurry, and nervous so that there are several completion steps that are miscalculated, missed not written, and not converted to the simplest form. This is compatible with previous research that the factors causing student errors in solving differential equations problems were due to their hasty attitude in working on the questions, students' lack of accuracy in observing the questions so they did not know if there was information that had not been included, lack of understanding of the material. delivered during lectures, and inadequate basic knowledge (Oktavia & Khotimah, 2016). Beside that, the causes of errors in general were because students did not optimize their prior knowledge regarding the concepts of derivatives and integrals and students did not fully understand the concepts and procedures in solving differential equations (Sulistyorini, 2017).

D. CONCLUSION AND SUGGESTIONS

Based on the results of the data analysis described above, it can be concluded that the types of student errors in solving non-homogeneous order n differential equations based on the Kastolan stages are: (1) conceptual errors consist of errors in use of formulas in answering questions and using a formula that is not in accordance with the conditions or prerequisites for the application of the formula, (2) procedural errors consist of errors because they can't solve the problem in the simplest form because they cannot continue the completion step, (3) technical errors consist of error in calculating the value of an arithmetic operation, errors in writing, namely there are constants or variables that are written wrong or missed or errors move constants or variables from one step to the next, and improper in

substituting values into variables. While the factors that cause student errors in solving problems of non-homogeneous order n differential equations are students who do not understand the prerequisite materials needed to solve problems of non-homogeneous order n differential equations, namely the concept of derivatives and general solutions of homogeneous differential equations, students also do not understand the concept determine the general form of a special solution (y_k) with certain prerequisites, students' skills in performing arithmetic operations are still lacking, less thorough, in a hurry, and nervous so that there are several completion steps that are miscalculated, missed not written, and not converted to the simplest form.

The suggestions that the researcher can convey are as follows: (1) to obtain wider research results, further research is needed regarding the analysis of student errors in solving non-homogeneous differential equations, which is not only limited to the method of solving using the method of indeterminate coefficients but can also be investigated. in other solving methods such as the parameter variation method and the inverse operator method, the differential equation problem solving test can also be made more varied, for example on exponential, sinusoidal functions or a combination of polynomials, exponentials, and sinusoids; (2) in the implementation of lectures, especially in discussing the material of non-homogeneous order differential equations, it is necessary for the lecturer's ability to choose the right solution methods, strategies and lecture techniques so as to make it easier for students to solve problems of non-homogeneous order n differential equations

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