p-ISSN: 2086-4280
e-ISSN: 2527-8827

Field Dependent Student Errors in Solving Linear Algebra Problems Based on Newman's Procedure

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Article accepted: 15-06-2022, revised: 18-01-2023, published: 31-01-2023

Abstrak
Masih banyak ditemui mahasiswa yang melakukan kesalahan dalam menyelesaiakan masalah Aljabar Linier khususnya pada materi Sistem Persamaan Linier. Penelitian ini bertujuan untuk mendeskripsikan jenis dan faktor penyebab kesalahan mahasiswa *field dependent* (FD) dalam menyelesaikan masalah Aljabar linier berdasarkan tahapan Newman. Penelitian ini dilakukan dengan pendekatan kualitatif dengan subjek penelitian 28 mahasiswa Program Studi Pendidikan Matematika Universitas PGRI Adi Buana Surabaya Angkatan 2020. Teknik pengumpulan data dengan mengunakan tes dan wawancara. Pada tahap pertama dilakukan tes GEFT untuk mengetahui gaya kognitif setiap mahasiswa, selanjutnya mahasiswa dengan gaya kognitif FD diberikan tes penyelesaian masalah Aljabar Linier, kemudian dipilih 3 mahasiswa FD dengan kemampuan menyelesaikan masalah terendah untuk dilakukan wawancara. Teknik analisis data menggunakan Miles and Huberman yang meliputi reduksi data, penyajian data, dan penarikan kesimpulan. Berdasarkan hasil penelitian dapat disimpulkan bahwa kesalahan mahasiswa dalam menyelesaikan masalah aljabar linier terletak pada tahap transformasi, keterampilan proses, dan penulisan jawaban dimana mahasiswa masih mengalami kesalahan dalam penentuan operasi baris elementer dan proses perhitungan. Sedangkan faktor penyebab kesalahan mahasiswa tersebut dikarenakan adanya kesalahan pemahaman konsep, kesalahan dalam menghitung, dan kurang teliti dalam mengerjakan.
Kata Kunci: aljabar linier; analisis kesalahan; *field dependent*; newman; sistem persamaan linier.

Abstract
Many students still make mistakes in solving Linear Algebra problems, especially in Linear Equation Systems material. This study aims to describe the types and factors that cause student error field dependent(FD) in solving linear algebra problems based on Newman's stages. This research was conducted using a qualitative approach with research subjects 28 students of the Mathematics Education Study Program at PGRI Adi Buana University Surabaya Class of 2020. Data collection techniques used tests and interviews. In the first stage, the GEFT test was carried out to determine the cognitive style of each student. Then students with the FD cognitive style were given a Linear Algebra problem-solving test, and then 3 FD students with the lowest problem-solving abilities were selected for interviews. The data analysis technique uses Miles and Huberman, including data reduction, presentation, and conclusion. Based on the study results, it can be concluded that student errors in solving linear algebra problems lie in the stages of transformation, processing skills, and writing answers, where students still experience errors in determining elementary row operations and calculation processes. While the factors that cause student errors are errors in understanding concepts, errors in calculating, and inaccuracy in working. And writing answers where students still experience errors in determining elementary row operations and the calculation process.
Keywords: linear algebra; error analysis; field-dependent; Newman; the system of linear equations.

I. INTRODUCTION

Linear Algebra is one of the subjects that students of the Mathematics Education study program must take. In the Linear Algebra course, students are expected to be able to understand the concept of matrices and solve Systems of Linear Equations, Vectors, and Linear transformations. Not only memorizing formulas, but students are also required to understand concepts so they can apply them in problem-solving (Hartati, 2019; Disparrilla & Afriansyah, 2022).

However, many students still fail Linear Algebra courses, as conveyed byLembang & Ba'ru (2018). It was found that students still experienced many difficulties when learning linear algebra, especially in the matter of systems of linear equations (SPL) using the Gauss-Jordan method. (Ramadhani, 2017; Pradiarti & Subanji, 2022). In addition, students also experience difficulties in concluding the correct solution, especially in SPL, which has many answers, and SPL which does not have a solution (Vitantri, 2021). Furthermore, Lembang and Ba'ru (2018) explained that some students had difficulty reducing rows, did not know the systematics of solving problems, and forgot formulas.

Student errors in solving Linear Algebra problems need to be analyzed further to find out the location of the errors and the causes of these errors so that a clear and detailed picture of student weaknesses in solving linear algebra problems is obtained. One method that can be used to analyze the mistakes in solving Linear Algebra problems is Newman's Error Analysis (NEA), as presented by Triliana and Asih (2019). also Lestari and Afriansyah (2022); through the stages of NEA, it can be known the location and causes of students making mistakes in solving mathematical problems. The steps of NEA include: 1) reading questions (reading), 2) understanding the problem (comprehension), 3) transformation (transformation), 4) process skills (process skills), and 5) writing the final answer (encoding). ((Ken) Clements, 1980).

Solving mathematical problems, primarily linear algebra, is necessary to solve the issues and a good and reflective thinking process (Reskiah et al, 2017; Muniri & Yulistiyah, 2022). This thinking process is closely related to the cognitive style of students. Cognitive techniques can be grouped into two types based on a person's psychological aspects in interacting with their environment, namely the Field Independence (FI) cognitive style and the Field Dependence (FD) cognitive style. This cognitive style grouping uses a particular test instrument, namely *Group Embedded Figures Test*(GEFT) developed by Witkin (1973).

Ramadani (2017) in his research, he said that students with the FI cognitive style type tended to make mistakes in concluding, while students with the FD cognitive style type tended to make procedural errors in using work procedures, errors in organizing data, errors in systematic manipulation and mistakes in concluding when completing linear algebra problem. According to Nugraha and Awalliyah (2016), in the learning process, someone with the characteristics of the FD cognitive style will tend to focus on general descriptions and only follow current information. Whereas someone with the features of the FI cognitive style will tend to find more information outside of existing content, be able to distinguish an object from surrounding objects more efficiently, and tend to be more analytic, and his motivation depends on an internal basis. Based on these studies, it can be concluded that someone with the characteristics of the FD cognitive style tends to make more mistakes in problem-solving. The results of several studies also support the previous statement that the problem-solving abilities of someone with the FI cognitive style tend to be better than FD students (Anthycamurty et al., 2018; Son et al., 2020; Sudarman et al., 2016).

Based on the above background, research on student error analysis in solving linear algebra problems in terms of FD cognitive style is vital to do to provide an overview of the location and causes of errors made by FD students so that lecturers can take corrective steps to minimize the mistakes made by students FD.

II. Method

This study uses a qualitative approach to describe the location and causes of field-dependent students' errors in solving linear algebra problems. This research was conducted in an odd semester of the 2021-2022 academic year, with students of the Class of 2020 in the Mathematics Education Study Program, PGRI Adi Buana University, Surabaya, as the research subjects. In the first stage, the Group Embedded Figures Test (GEFT) was carried out to determine the cognitive style of each student in Batch 2020. The GEFT test consists of three steps; the first consists of 7 questions and functions as an exercise, so the results are not taken into account, then the second and third steps, respectively - each consists of 9 queries. The test is done within 15 minutes; each question is scored 1 (one) for the correct answer and 0 (zero) for the wrong answer (Puspananda & Suriyah, 2017).

The next step is for students with the FD cognitive style to be given a Linear Algebra problem-solving test in the sub-discussion of solving Linear Equation Systems with Elementary Row Operations (OBE), which consists of 3 description questions. Then, from the test results, 3 FD students with the lowest problem-solving ability were selected to be interviewed. The interview aims to confirm student answers and to dig up information about the location and causes of student errors in solving linear algebra problems.

Furthermore, data analysis was conducted by describing the data obtained from tests and interviews to answer the problem formulation. Researchers used the Miles and Huberman analysis model (Sugiyono, 2017), which includes data reduction, data presentation, and conclusion. At the data reduction stage, the researcher simplified the data obtained from the results of tests and interviews by paying attention to the error indicators in Newman's theory. As for the hands of Newman's mistakes, according to Elsa and Sudihartinih (2020) presented in Table 1 below.

Table 1.
Error Indicator based on Newman's Theory

Error Type	Error Indicator
a. Reading (read)	Errors in reading, recognizing, and understanding symbols/terms in questions and mistakes in interpreting the purpose of the questions
b. Comprehension (understand)	Errors in understanding information and understanding question commands
c. Transformation (transformation)	1) Error in making a mathematical model from the information contained in the problem 2) Errors in determining formulas/calculation operations to be used to solve problems.
d. Process Skills (process skills)	Errors in carrying out procedures or steps used to solve problems
e. Encoding (answer writing)	1) Unable to write the complete and correct final answer 2) Cannot/forgot to write down the definitive answer according to the question command.

At the data presentation stage, the reduced data is then triangulated using technical triangulation to ensure the validity of the data. Furthermore, the data is presented as a concise and precise description of the types of errors and their causative factors. Finally, the researcher concludes by paying attention to the purpose of the research.

III. RESULT AND DISCUSSION

The first step in this study was the GEFT test for 28 students, and the results showed that one student was included in the field-independent (FI) cognitive style category, and 27 students were included in the field-dependent (FD) cognitive style category. Furthermore, field-dependent students are given a problem-solving test in the form of 3 description questions with material on a system of linear equations. Then from the test results obtained, three field-dependent students with the lowest scores for error analysis according to Newman's stages, which include reading, understanding, transformation, processing skills, and writing answers. The following describes the test analysis results of the three subjects with a field-dependent cognitive style in solving linear algebraic problems in the material system of linear equations.

A. Subject Error Analysis 1

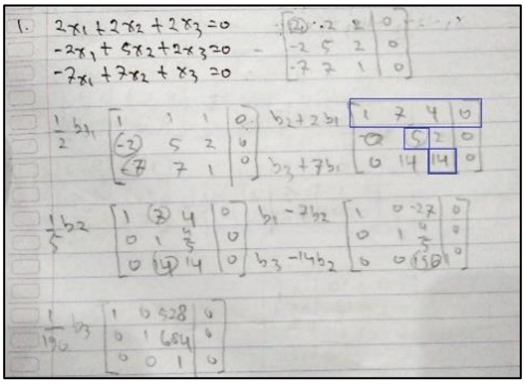

Figure 1. Answers to Test Number 1 Subject 1

In question number 1, based on the test results as shown in Figure 1, subject 1 made an error at the process skills stage where subject 1 was wrong in doing the calculations in the third matrix when changing the second and third rows, namely in the 2nd line which should be (0 7 4) but answered (0 5 2) and in the 3rd line it should be (0 14 8) answered (0 14 14), additionally on the first line which should be unchanged but changed. The data was also confirmed from the interview results, where subject 1 stated that the results in the first line should be the answer in the second line. The error was due to subject one being in a hurry in doing so that the respondent was not careful in the calculations. The impact of these errors resulted in obtaining final results that were not appropriate. In addition, subject one also did not write the conclusion of answer number 1.

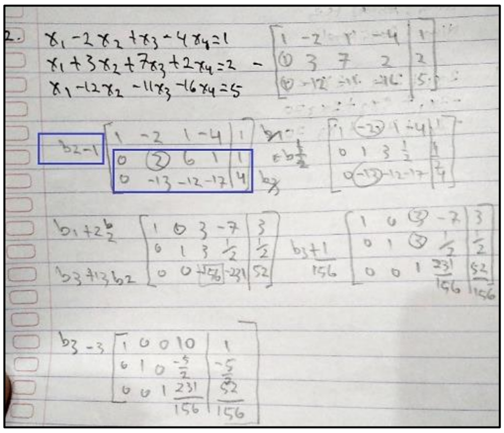

Figure 2. Answers to Test Number 2 Subject 1

Furthermore, in question number 2, based on Figure 2, subject 1 made a mistake at the transformation stage where subject 1 was wrong in determining the operation to be carried out; it should have been b2-2b1 but answered b2-1. Based on the interview results, subject 1 justified the error caused by an error in understanding the concept that the operation in OBE is to subtract a row with a multiple of a particular row, not with a constant. The data is in line with what Oktafia et al. (2020) said the transformation error is caused by a person's inability to determine the correct sequence of operations to solve the problem.

The impact of these errors resulted in obtaining final results that were not appropriate. Subject 1 also did not write down the conclusion of the definitive answer the respondent received. Thus, subject 1 made mistakes during the transformation and answer writing stages.

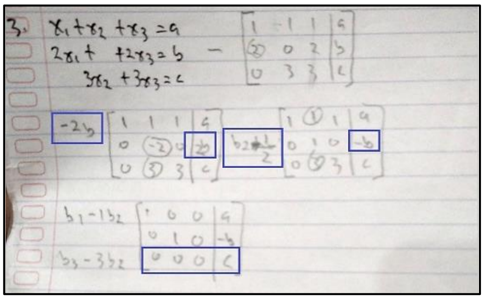

Figure 3. Answers to Test Number 3 Subject 1

In question number 3, as shown in Figure 3, subject 1 made a mistake at the transformation stage where subject 1 was wrong in determining the operation to be carried out; it should have been b2-2b1 but answered -2b. This answer follows the interview results where subject 1 realized a misunderstanding of the concept in OBE caused the error. In addition, subject one also made mistakes at the stage of process skills, where subject 1 made mistakes in calculating predetermined operations. The impact of these errors resulted in obtaining final results that were not appropriate. Subject 1 also did not write down the conclusion of the definitive answer he received. Thus, subject 1 made mistakes at the transformation stage, processing skills, and writing answers.

B. Subject Error Analysis 2

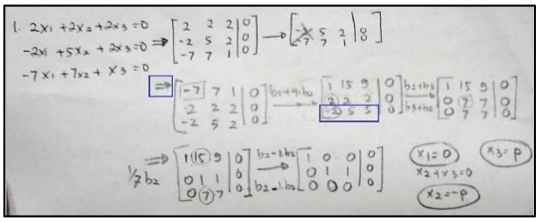

Figure 4. Answers to Test Number 1 Subject 2

In question number 1, based on Figure 4, subject 2 made an error in the transformation stage where subject two did not write down the operations used in the first-row operations. The data confirmed from the interview results that subject two was still confused in determining OBE. In addition, subject two also made an error at the stage of processing skills where the subject 2 was wrong in rewriting the third line in the second line operation due to inaccuracy and rush. The impact of this error resulted in obtaining an inappropriate final result even though subject two had written the final answer. Thus, subject 2 made mistakes at the transformation stage, processing skills, and corresponding solutions.

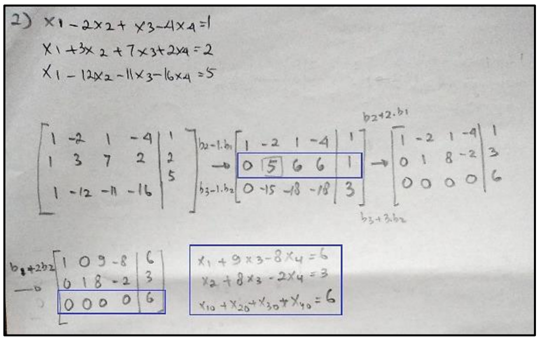

Figure 5. Answers to Test Number 2 Subject 2

Furthermore, at number 2, based on the answers in Figure 5, subject 2 made an error at the process skills stage wherein the second matrix, the second row of the calculation results, did not match the specified operations. The data is supported by the interview results where subject 2 misunderstood the concept that what is operated directly on the second column is not all the elements in that row. In addition, subject two also made an error in writing the final answer where subject 2 was wrong in determining the definitive answer, which should be when the coefficients of the third row of the matrix all have a value of 0 with the correct value, not 0, the conclusion is that the system of linear equations has no solution. Thus, it can be concluded that subject 2 made a mistake at the answer writing stage.

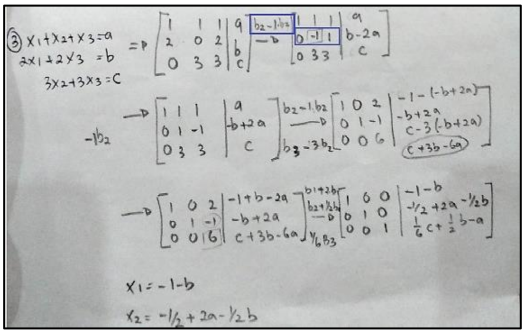

Figure 6. Answers to Test Number 3 Subject 2

In question number 3, based on the answer in Figure 6, subject 2 made a mistake at the transformation stage where subject 2 was wrong in determining the row 1 operation, which should be b2-2b1, not b2-1b2. The result has also been confirmed from the interviews where subject 2 misunderstood the concept that the process in OBE is to subtract a row by multiples of specific other rows, not removing its row. Subject 2 also made an error at the stage of process skills where subject 2 was wrong in calculating predetermined row operations. The impact of this error resulted in obtaining the final results that were not appropriate even though subject two had written the conclusions of the final answers obtained. Thus, subject 2 made a mistake at the stage of transformation, process skills.

C. Subject Error Analysis 3

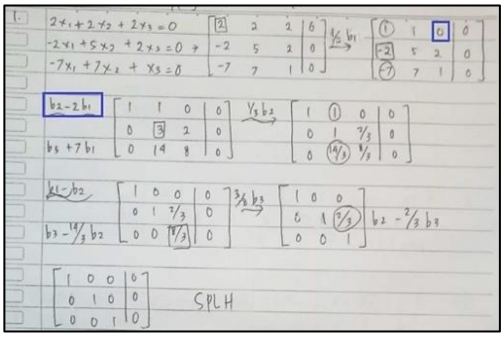

Figure 7. Answers to Test Number 1 Subject 3

In question number 1, based on the answer in Figure 7, subject 3 made an error at the process skills stage where subject 3 made a mistake in doing the calculation when changing the first row of the third column where the value of 1 should be the same as the first row of the second column, not 0. Apart from that, subject three also made a mistake at the transformation stage where subject 3 was wrong in determining the second line operation, namely b2-2b1, which should be b2+2b1. Based on the interview results, subject three was not careful in calculating and choosing OBE. The impact of these errors resulted in obtaining final results that were not appropriate. Subject 3 also did not write down the conclusion of answer number 1. Thus, subject 3 made mistakes in the process skills, transformation, and answer writing stages.

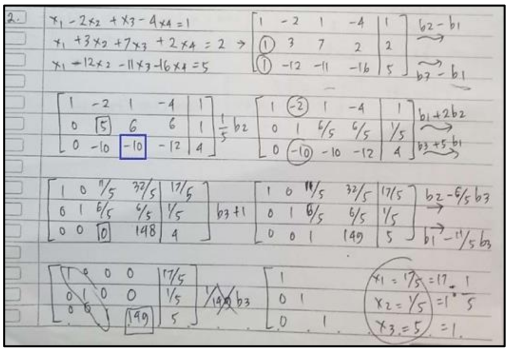

Figure 8. Answers to Test Number 2 Subject 3

Furthermore, in question number 2, based on Figure 8, subject 3 made a mistake at the process skills stage where subject 3 was wrong in carrying out the calculations that had been determined, which should have been in the second matrix row 3 column 3 the calculation results were -12 but answered -10. The analysis is in line with what Sutama and Indriyani (2021) said: process skill errors occur when students can determine the appropriate sequence of operations but cannot carry out the procedure correctly.

Based on the confirmation results from the interview, subject three was not careful in carrying out the calculations, so it impacted the final results that were not appropriate even though subject three had written the conclusion of the definitive answer he obtained. Thus, in question number 2, subject 3 made a mistake in processing skills and writing answers.

In question number 3, based on the answer in Figure 9, subject 3 made a mistake at the process skills stage where subject 3 made an error in calculating the predetermined operations, which should have been in the second matrix row 2 column 3; the result was 0 but written -2 as in question number 2 which is caused by inaccuracy in the calculations. The impact of these errors resulted in obtaining final results that were not appropriate. Subject 3 also did not write down the conclusion of the definitive answer the respondent obtained. Thus, subject 3 made a mistake when processing skills and writing answers.

Based on the error analysis of the three subjects, it can be concluded that the types and factors that cause FD student errors in solving linear algebra problems are shown in Table 2.

Table 2.
Results of Student Error Analysis
Dependent Fields in Solving Linear Algebra Problems

Subject	No. About	Type Error	Factor Reason
1	1	Process skills, Writing answers	Inaccurate in calculations
	2	Transformation, Writing answers	concept error
	3	Transformation, Process skills, Writing answers	conceptual error, miscalculation
2	1	Transformation, Process skills, Writing answers	Misconception, Inaccuracy
	2	Answer writing	Concept error
	3	Transformation, Process skills, Writing answers	conceptual error, miscalculation
3	1	Transformation, Process skills, Writing answers	Misconception, Inaccuracy
	2	Process skills and writing answers	Not Careful
	3	Process skills and writing answers	Not Careful

Based on Table 2, it can be concluded that subjects with the FD cognitive style in solving problems with systems of linear equations made many mistakes at the transformation stage in determining row operations, processing skills in calculations, and writing answers which were the impact of the previous stage's errors. These results follow the Ratnaningsih et al. (2020) study, where subjects with the FD cognitive style tend to make mistakes in the transformation stage, process skills in the calculation process, and draw conclusions caused by errors in the previous step. Ramadani (2017), also Kristianti and Retnawati (2020) added that subjects with the FD cognitive style tend to make mistakes in using elementary row operations and are less careful in checking answers, so they experience errors in Writing answers when solving linear algebra problems. Whereas Agoestanto et al. (2019) and Nasution (2019) mentioned that apart from the stages of transformation, process skills, and writing answers, FD subjects also tended to make mistakes at the stage of understanding the problem where FD subjects did not understand the purpose of the given issues.

Meanwhile, most of the mistakes made by FD subjects in solving SST problems occurred due to conceptual errors or inaccuracies in the calculations. According to the Agoestanto et al. (2019) and Sa’dijah et al. (2020) research results, the mistakes made by FD subjects were caused by FD subjects' lack of understanding of the concept and inaccuracy in calculating solutions to linear equations. Sepúlveda et al. (2019), also Wiyah and Nurjanah (2021) added that errors in solving SPL problems are caused by a lack of time to understand the problem, inaccuracy in performing calculations, and a lack of understanding of concepts. Khairani and Kartini (2021) and Gustianingum and Kartini (2021) also mentioned that errors in understanding concepts mainly cause errors in solving mathematical problems. With the results of this study, it is hoped that it will further add to the information about the types and causes of student errors in solving linear algebra problems, especially material for systems of linear equations so that in the future, lecturers can find the right solution by developing learning and research to find answers to the types and causes of these errors to minimize students' mistakes.

IV. CONCLUSION

Based on the results of the study, it can be concluded that the errors of students with the FD cognitive style in solving linear algebra problems in SPL material are located in: 1) the transformation stage, namely the student's error in determining the correct Elementary Row Operation (OBE) to solve the problem, 2) At the stage process skills, namely students make mistakes in the calculation process, and 3) At the answer writing stage, namely errors in writing the final results caused by errors in the previous stage.

The factors that cause student errors with the FD cognitive style in solving problems with systems of linear equations are errors in understanding the concept, errors in calculating, and inaccuracy in working.

With information related to the characteristics of students' cognitive styles as well as the location of errors and factors that cause students to solve this Linear Algebra problem, it is hoped that this can be used as evaluation material for lecturers supporting Linear Algebra courses in preparing a better learning process so that the same mistakes can be minimized.

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