ISSN 2303-0992
ISSN online 2621-3176
Matematika dan Pembelajaran
Volume 11, No. 2, December 2023, h. 169-181
Submitted: October 9, 2023; **Revised**: November 7, 2023; **Accepted**: November 10, 2023

PROCEDURAL KNOWLEDGE-BASED STRATEGIES IN IMPROVING STUDENT LEARNING OUTCOMES IN ORDINARY DIFFERENTIAL EQUATIONS COURSES

Dina Amalya Lapele[1], Adam Bin Haji Jait[2]
[1]*Institut Agama Islam Negeri Ambon, Indonesia*
[2]*University Islam Sulthan Sharif Ali, Brunei Darussalam*

dina14amalya03@iainambon.ac.id

Abstrak

Penelitian ini bertujuan untuk mengidentifikasi perbedaan rata-rata hasil belajar antara mahasiswa yang diajarkan dengan menggunakan strategi berbasis pengetahuan prosedural dan mahasiswa yang diajarkan tanpa menggunakan strategi berbasis pengetahuan prosedural. Penelitian ini merupakan penelitian quasi-eksperimental dengan desain *posttest-only design with nonequivalent groups*. Populasi pada penelitian ini yaitu mahasiswa Program Studi Pendidikan Matematika IAIN Ambon. Sampel yang digunakan yaitu mahasiswa Program Studi Pendidikan Matematika IAIN Ambon Semester 3 (kelas A dan kelas B). Jumlah mahasiswa kelas A yaitu 14 orang dan jumlah mahasiswa kelas B juga 14 orang. Teknik pengumpulan data dalam penelitian ini yaitu tes. Instrumen yang digunakan berupa soal tes. Soal tes tersebut terdiri dari tiga soal uraian tentang berbagai jenis persamaan diferensial biasa. Teknik analisis data yang digunakan yaitu Mann Whitney U Test dan uji deksriptif. Hasil penelitian menunjukkan terdapat perbedaan rata-rata hasil belajar antara mahasiswa yang diajarkan dengan menggunakan strategi berbasis pengetahuan prosedural (kelas eksperimen) dan mahasiswa yang diajarkan tanpa menggunakan strategi berbasis pengetahuan prosedural (kelas kontrol). Rata-rata hasil belajar mahasiswa kelas eksperimen lebih tinggi dibandingkan rata-rata hasil belajar mahasiswa kelas kontrol. Dapat disimpulkan bahwa strategi berbasis pengetahuan prosedural dapat meningkatkan hasil belajar mahasiswa dalam mata kuliah Persamaan Diferensial Biasa.
Kata kunci: Hasil Belajar; Pengetahuan Prosedural; Persamaan Diferensial Biasa; Strategi

Abstract

This research aims to identify the differences in average learning outcomes between students taught using procedural knowledge-based strategies and students who are taught without using procedural knowledge-based strategies. This research is quasi experimental research with a posttest-only design with nonequivalent groups. The population in this study were students from the Mathematics Education Department at IAIN Ambon. The samples were students of third semester (class A and class B). The number of class A students is 14 people and the number of class B students is same. The data collection technique in this research was tests. The instrument is test questions. The test questions consist of three questions describing various types of ordinary differential equations. The data analysis technique were the Mann Whitney U Test and descriptive test. The research results showed that there were

differences in average learning outcomes between students who were taught using procedural knowledge-based strategies (experimental class) and students who were taught without using procedural knowledge-based strategies (control class). The average learning outcomes of experimental class students is higher than the average learning outcomes of control class students. It can be concluded that procedural knowledge-based strategies can improve student learning outcomes in the Ordinary Differential Equations course.
Keywords: Learning Outcomes; Ordinary Differential Equations; Procedural Knowledge; Strategy

Citation: Lapele, D. A & Jait, A. B. H., 2023. Procedural Knowledge-Based Strategies in Improving Student Learning Outcomes in Ordinary Differential Equations Courses. *Matematika dan Pembelajaran*, 11(2), 169-181. DOI: http://dx.doi.org/10.33477/mp.v11i2.5547

INTRODUCTION

Mathematics learning is largely shaped by teachers through the various tasks given and the strategies used in them (Vale & Barbosa, 2023). This means that learning strategies are an important thing that determines how learning takes place. Learning strategies are defined as methods that teachers use to form constructive students in a particular lesson, through the demonstration of different skills needed over time (Oginni et al., 2021).

Teachers can choose to use any learning strategy that suits their students' needs. In learning practice, teachers need to make choices about what learning strategies will be used as the basis for daily learning activities (Hurrell, 2021). One strategy that can be used is a strategy using a procedural knowledge approach. Procedural knowledge is knowledge of procedures in solving mathematical problems (Yurniwati, 2018). Procedural knowledge refers to knowledge of problem-solving procedures, such as step-by-step algorithms that are taught to students (Braithwaite & Sprague, 2021). Thus, procedural knowledge-based strategies can be carried out by focusing learning on the steps to find solutions in solving problems. Procedural knowledge-based strategies are very important because students need procedural knowledge to solve mathematical problems (Nahdi & Jatisunda, 2020).

One of the most important subjects in mathematics is ordinary differential equations. An ordinary differential equation is an equation that contains one or more functions of a single independent variable in its derivative (Kurniadi et al., 2022). This course is very important because it is related to other scientific disciplines such as biology, physics, chemistry, pharmacy, psychology, economics, and others (Yarman, 2018).

In reality, students still experience difficulties in ordinary differential equations courses. The difficulty experienced by students is in solving the initial value problem algorithm (Farlina et al., 2018). The facts obtained are that 65% of students have not been able to complete the proof, 35% of students have not used the proof algorithm, and all students have not carried out verification checks. Students are not skilled in using formulas, are not careful, and have a habit of not repeating lessons they have learned previously (Yarman et al., 2020).

Procedural knowledge-based learning strategies can be used in ordinary differential equations courses. Procedural knowledge-based learning strategies are very appropriate to use in this course because most of the problems studied in this course are routine problems that require procedural understanding. This is in line with the statement by Braithwaite & Sprague (2021) which states that procedural knowledge can be used in solving routine problems.

There are several studies that are relevant to this research. Several studies have examined various topics of mathematics learning strategies. Khanal et al. (2021) conducted research on mathematics learning strategies in senior secondary schools in Nepal. The results of the research show that there are 9 types of learning strategies used, namely peer learning, elaboration, help-seeking, effort management, rehearsal, organization, time and study management, metacognition, and critical thinking. Vale & Barbosa (2023) conducted research on active learning strategies in effective mathematics learning. The results of the research show that the use of active learning strategies is very meaningful in learning. Wu et al. (2021) conducted research on learning strategies as a moderator between motivation and

mathematics performance in East Asian students. The results of the research show the moderating effect of using learning strategies on mathematics performance depending on the type of motivation and educational system.

Several other studies have also examined procedural understanding. Yurniwati (2018) conducted research on the use of a multisensory approach to improve conceptual and procedural understanding. The results of the research show that the multisensory approach can improve conceptual and procedural understanding. Nahdi & Jatisunda (2020) conducted research on case studies on conceptual knowledge and procedural knowledge in fraction material in elementary schools. The results of the research show that students who have conceptual and procedural knowledge can build good knowledge in learning mathematics. Klau et al. (2020) conducted research aimed at identifying conceptual and procedural understanding in prospective secondary teachers. The results of the research show that teachers try to answer questions using a procedural approach.

There are also several studies that focus on ordinary differential equations. Lozada et al. (2021) conducted research on classroom management methodology for learning ordinary differential equations. The results of the research are in the form of a literature review and biometric analysis of various classroom management methodologies in ordinary differential equations courses. Kurniadi et al. (2022) conducted research on learning ordinary differential equations at undergraduate level. The results of his research present various topics studied in ordinary differential equations courses, as well as the methods and sources used.

Previous research only examined the learning of ordinary differential equations in general, namely regarding classroom management methods. Previous research also only examined data regarding references in learning differential equations courses. There has been no research that examines specific strategies that can be applied to improve student learning outcomes in ordinary differential equations courses.

This research focuses on the use of procedural knowledge-based learning strategies in ordinary differential equations courses. This research will investigate whether there is an average difference in the learning outcomes of students who are taught using procedural knowledge-based learning strategies and students who are taught without using procedural knowledge-based learning strategies. This research is very important because the learning outcomes in the Ordinary Differential Equations course are still not optimal. One effort that can be made is to use appropriate learning strategies that are in accordance with the characteristics of the course which contains many procedures. Procedural knowledge-based learning strategies are the right solution to improve learning outcomes.

METHOD

This research is a quasi-experimental research which aims to identify whether there is a difference in average learning outcomes between students who are taught using procedural knowledge-based strategies and students who are taught without using procedural knowledge-based strategies. The population of this research is students of the Mathematics Education Study Program at IAIN Ambon. The samples used were students of the IAIN Ambon Mathematics Education Study Program, third semester (class A and class B). The research design used was a posttest-only design with nonequivalent groups. This research design can be seen in the following table (Hastjarjo, 2019).

Table 1. Posttest-Only Design With Nonequivalent Groups

Class	Treatment	Post Test
Experiment	X	Y_1
Control	-	Y_2

Description :

X : procedural knowledge based strategies

Y_1 : learning outcomes of experiment class

Y_2 : learning outcomes of control class

The data collection technique used is a test. The instrument used is descriptive test questions. The test questions consist of three questions containing various types of ordinary differential equations. The first question is a question about separate differential equations, the second question is about homogeneous differential equations, and the third question is about exact differential equations. The data analysis techniques used are descriptive quantitative analysis and the Mann Whitney U Test. Descriptive analysis was used to determine the average learning outcomes of the experimental class and control class. The Mann Whitney U Test was used to test whether there was a difference in average learning outcomes between students who were taught using procedural knowledge-based strategies and students who were taught without using procedural knowledge-based strategies. The data in this study were analyzed using the Statistical Package for the Social Sciences (SPSS) Version 25.

RESULT AND DISCUSSION

This research was carried out on students of the IAIN Ambon Mathematics Education Study Program, third semester. The students were divided into two classes, namely the experimental class (class A) and the control class (class B). The experimental class was taught ordinary differential equations using procedural knowledge-based strategies. The control class was taught ordinary differential equations without using procedural knowledge-based strategies. After the entire series of learning has been completed, at the final meeting students are given a test to identify whether there is a difference in average scores between the experimental class and the control class. Normality and homogeneity tests were then carried out to ensure the use of the Mann Whitney test.

Normality Test

The normality test is carried out to check whether the data is normally distributed or not. The following is a table of normality test results.

Table 2. Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Score	.222	28	.001	.897	28	.010

a. Lilliefors Significance Correction

It can be seen that the Kolmogorov-Smirnov Sig value is 0.001 < 0.05. So based on the Komogorov-Smirnov test, the data is declared not normally distributed. The normality test can also be carried out using Shapiro-Wilk. In the Shapiro-Wilk test, the Sig value was obtained, namely 0.010 < 0.05. This means the data is not normally distributed. Thus, the data will then be analyzed using non-parametric statistics because the data is not normally distributed.

Homogenity Test

The homogeneity test is carried out to ensure that the data is homogeneous or that the data comes from the same variant. The homogeneity test was carried out using Levene Statistics.

Table 3. Test of Homogenity of Variances

		Levene Statistic	df1	df2	Sig.
Score	Based on Mean	.509	1	26	.482
	Based on Median	.603	1	26	.445
	Based on Median and with adjusted df	.603	1	25.894	.445
	Based on trimmed mean	.553	1	26	.464

Based on the table above, it can be seen that the Sig Based on Mean value is 0.482 > 0.05. This states that the variants of the two classes are the same or homogeneous. Because the data is not normally distributed and is homogeneous, hypothesis testing will be carried out using the Mann Whitney U Test.

Hypothesis Test

Hypothesis testing is used to investigate whether the accepted hypothesis is Ho or Ha. Ho stated that there was no difference in average learning outcomes

between students who were taught using procedural knowledge-based strategies and students who were taught without using procedural knowledge-based strategies. Ha stated that there was a difference in average learning outcomes between students who were taught using procedural knowledge-based strategies and students who were taught without using procedural knowledge-based strategies. Hypothesis testing was carried out using the Mann Whitney U Test. Following are the results of the Mann Whitney U Test.

Tabel 4. Ranks

	Class	N	Mean Rank	Sum of Ranks
Score	Control	14	10.71	150.00
	Experiment	14	18.29	256.00
	Total	28		

The sum of ranks of the control class is 150 and the sum of ranks of the experimental class is 256. This means that the sum of ranks of the experimental class is greater than the control class. The mean rank of the control class is 10.71 and the mean rank of the experimental class is 18.29. This means that the mean rank of the experimental class is higher than the control class.

Tabel 5. Test Statistics[a]

	Score
Mann-Whitney U	45.000
Wilcoxon W	150.000
Z	-2.443
Asymp. Sig. (2-tailed)	.015
Exact Sig. [2*(1-tailed Sig.)]	.014[b]

a. Grouping Variable: Class
b. Not corrected for ties.

Based on the table above, it can be seen that the value of Asymp. Sig. (2-tailed) namely 0.015 < 0.05. This means Ho is rejected or Ha is accepted. Thus it can be stated that there is a difference in average learning outcomes between students who are taught using procedural knowledge-based strategies and students who are taught without using procedural knowledge-based strategies.

Descriptive Test

Table 6. Descriptive

	Class			Statistic	Std. Error
Score	Control	Mean		76.36	2.506
		95% Confidence Interval for Mean	Lower Bound	70.94	
			Upper Bound	81.77	
		5% Trimmed Mean		76.23	
		Median		75.00	
		Variance		87.940	
		Std. Deviation		9.378	
		Minimum		65	
		Maximum		90	
		Range		25	
		Interquartile Range		20	
		Skewness		.353	.597
		Kurtosis		-1.349	1.154
	Experiment	Mean		85.86	2.161
		95% Confidence Interval for Mean	Lower Bound	81.19	
			Upper Bound	90.53	
		5% Trimmed Mean		86.23	
		Median		88.00	
		Variance		65.363	
		Std. Deviation		8.085	
		Minimum		70	
		Maximum		95	
		Range		25	
		Interquartile Range		14	
		Skewness		-.956	.597
		Kurtosis		-.395	1.154

Based on the table above, it can be seen that the control class obtained an average score of 76.36 while the experimental class obtained an average score of 85.86. This means that the average value of the experimental class is higher than the control class. In the descriptive test, it was seen that the experimental class had a minimum score of 70 and the control class had a minimum score of 65. Students in the control class admitted that they had difficulty doing their assignments at each meeting.

The learning strategy applied in the experimental class is a learning strategy based on procedural knowledge. Strategies like this are widely used by

other teachers. Most teachers answer student questions using a procedural approach (Klau et al., 2020). Procedures are a series of steps or actions required to achieve a task or achieve a goal (Rittle-Johnson, 2017). Procedural knowledge is a series of steps that must be followed to solve mathematical problems. This knowledge includes algorithmic, technical skills, methods, as well as knowledge of the criteria by which a procedure must be used (Nahdi & Jatisunda, 2020).

The learning outcomes average of the experimental class is higher than the control class. This is also supported by the maximum and minimum values of the two classes. This fact is in line with Nahdi & Jatisunda (2020) that procedural knowledge is one of the factors that can build good knowledge in studying mathematics.

In the descriptive test, it was seen that the experimental class had a minimum score that higher than control class. Students in the control class admitted that they had difficulty doing their assignments at each meeting. They are unable to explain the results of their work if they do not have procedural knowledge (Nahdi & Jatisunda, 2020). Students sometimes do not have appropriate procedures for solving problems (Klau et al., 2020).

The procedural knowledge-based strategy in this research is carried out by carrying out learning based on steps in finding solutions based on the type of differential equation being studied. Students are also given an understanding of each step. This is because procedural knowledge also needs to be accompanied by an understanding of the procedure, not just following the steps (Hurrell, 2021).

Students who are taught using knowledge-based learning strategies obtain higher learning outcomes than students who are taught without using this strategy. This learning strategy gives students the opportunity to be actively involved. When students are given the opportunity to be actively involved in learning, this will increase their level of attention and understanding (Edwards, 2015). They will also enjoy the learning process more. This has a positive impact where enjoyment of

learning is the biggest influencing factor in determining performance (Lau & Ho, 2020).

The use of learning strategies based on procedural knowledge is very important in ordinary differential equations courses. This is because this course studies the stages of finding the right solution (Farlina et al., 2018). The procedure for finding a solution requires various formulas and mathematical rules. Procedural knowledge supports students to remember rules, procedures, principles and mathematical definitions to solve problems (Klau et al., 2020). Apart from that, procedural knowledge requires an understanding of objects, formats and syntax to express interpretations (Kadijevich, 2018).

This strategy focuses on solving routine problems only. This is because procedural understanding tends to focus on routine problems. Solving non-routine problems requires new and different steps or strategies compared to solving routine or ordinary problems (Kurniawan et al., 2017).

CONCLUSION

Procedural knowledge-based learning strategies have a positive impact on learning outcomes. Procedural knowledge-based learning strategies can improve student learning outcomes in ordinary differential equations courses. There is a difference in average learning outcomes between students who are taught using procedural knowledge-based learning strategies and students who are taught without using procedural knowledge-based learning strategies. Students who were taught using procedural knowledge strategies obtained higher average learning outcomes than students who were taught without using this strategy. This strategy is limited to solving routine problems only. Thus, it is hoped that further research can develop other strategies for solving non-routine problems.

REFERENCES

Braithwaite, D. W., & Sprague, L. (2021). Conceptual Knowledge, Procedural Knowledge, and Metacognition in Routine and Nonroutine Problem Solving.

Cognitive Science, *45*(10). https://doi.org/10.1111/cogs.13048

Edwards, S. (2015). Active learning in the middle grades. *Middle School Journal*, *46*, 26–32. https://doi.org/https://doi.org/10.1080/00940771.2015.11461922

Farlina, E., Rachmawati, T. K., Ariany, R. L., Widiastutia, T. T., & Sobarningsih, N. (2018). Ordinary differential equations: Students' difficulty in solve the algorithm of the initial value problem with the integrating factor method. *IOP Conference Series: Materials Science and Engineering*, *434*(1). https://doi.org/10.1088/1757-899X/434/1/012010

Hastjarjo, T. D. (2019). Rancangan Eksperimen-Kuasi. *Buletin Psikologi*, *27*(2), 187. https://doi.org/10.22146/buletinpsikologi.38619

Hurrell, D. (2021). Conceptual Knowledge OR Procedural Knowledge or Conceptual Knowledge AND Procedural Knowledge: Why the Conjunction is Important to Teachers. *Australian Journal of Teacher Education*, *46*(2), 57–71. https://doi.org/10.14221/ajte.2021v46n2.4

Kadijevich, D. M. (2018). Relating procedural and conceptual knowledge. *Teaching of Mathematics*, *21*(1), 15–28.

Khanal, B., Panthi, R. K., Kshetree, M. P., Acharya, B. R., & Belbase, S. (2021). Mathematics learning strategies of high school students in Nepal. *SN Social Sciences*, *1*(7), 1–28. https://doi.org/10.1007/s43545-021-00165-y

Klau, K. Y., Siahaan, M. M. L., & Simarmata, J. E. (2020). An Identification of Conceptual and Procedural Understanding: Study on Preservice Secondary Mathematics Teacher. *Al-Jabar : Jurnal Pendidikan Matematika*, *11*(2), 339–350. https://doi.org/10.24042/ajpm.v11i2.7310

Kurniadi, E., Zulkardi, Z., & Putri, R. I. I. (2022). Learning ordinary differential equation at undergraduate level: A systematic learning review. *Al-Jabar : Jurnal Pendidikan Matematika*, *13*(1), 23–31. https://doi.org/10.24042/ajpm.v13i1.10707

Kurniawan, E., Mulyati, S., & Rahardjo, S. (2017). Proses Asimilasi Dan Akomodasi. *Teori, Penelitian, Dan Pengembangan*, *2*(5), 592–598.

Lau, K. C., & Ho, S. C. E. (2020). Attitudes towards science, teaching practices, and science performance in PISA 2015: Multilevel analysis of the Chinese and Western top performers. *Research in Science Education. Advance Online Publication*. https://doi.org/https://doi.org/10.1007/s11165-020-09954-6

Lozada, E., Guerrero-Ortiz, C., Coronel, A., & Medina, R. (2021). Classroom methodologies for teaching and learning ordinary differential equations: A systemic literature review and bibliometric analysis. *Mathematics*, *9*(7). https://doi.org/10.3390/math9070745

Nahdi, D. S., & Jatisunda, M. G. (2020). Conceptual Understanding and Procedural Knowledge: A Case Study on Learning Mathematics of Fractional Material in Elementary School. *Journal of Physics: Conference Series*, *1477*(4). https://doi.org/10.1088/1742-6596/1477/4/042037

Oginni, O. I., Akinola, A. S., Fadiji, A. E., & Amole, P. A. (2021). Effects of Mastery Learning Strategy on Secondary School Students Performance in Mathematics. *European Journal of Education and Pedagogy*, *2*(5), 59–63. https://doi.org/10.24018/ejedu.2021.2.5.171

Rittle-Johnson, B. (2017). Developing Mathematics Knowledge. *Child Development Perspectives*, *11*(3), 184–190. https://doi.org/https://doi.org/10.1111/cdep.12229

Vale, I., & Barbosa, A. (2023). Active learning strategies for an effective mathematics teaching and learning. *European Journal of Science and Mathematics Education*, *11*(3), 573–588. https://doi.org/10.30935/scimath/13135

Wu, Y. J., Chen, Y. H., Kiefer, S. M., & Carstensen, C. H. (2021). Learning Strategies as Moderators Between Motivation and Mathematics Performance in East Asian Students: Latent Class Analysis. *SAGE Open*, *11*(4). https://doi.org/10.1177/21582440211061382

Yarman. (2018). Application of Connecting Learning Model-Organizing-Reflecting-Extending on The Ordinary Differential Equations Course. Advances in Social Science. *Education and Humanities Research (ASSEHR)*, *285*.

Yarman, Fauzan, A., Armiati, & Lufri. (2020). *Hypothetical Learning Trajectory for First-Order Ordinary Differential Equations*. *504*(ICoIE), 337–341. https://doi.org/10.2991/assehr.k.201209.245

Yurniwati, Y. (2018). Improving the Conceptual and Procedural Knowledge of Prospective Teachers through Multisensory Approach: Experience from Indonesia. *JRAMathEdu (Journal of Research and Advances in Mathematics Education)*, *3*(2), 106. https://doi.org/10.23917/jramathedu.v3i2.6374