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How the Exponential Function is Taught: A Praxeological Analysis of Indonesian Textbooks

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Abstract. *Multiplying repeated numbers yields an expression for exponent numbers. Numerous studies have shown that students still experience difficulties when learning exponents. A particular approach to assist students in overcoming their challenges is to use textbooks as a study resource. This study aims to evaluate the material provided in the Indonesian mathematics textbook about the exponent and exponential function subjects. This study employed a qualitative research design utilising a content analysis approach, using a mathematics textbook for observation and documentation. There were two primary stages to the analytical process: the logos bloc analysis and the praxis bloc analysis. The results showed that the Indonesian textbook organises exponents into two distinct local definitions of function: repeated multiplication and exponential function. There are four different kinds of tasks based on the praxis block. The definition of an exponent, the characteristics of the exponent, the exponential function, and the graph of the exponential function. Even though there are not many differences between formal and textbook definitions of exponential and exponential functions, textbook tasks tend to be repetitive, so it is important to include assignments that encourage students to think more critically and creatively.*

Keywords: *textbooks, praxeology, exponent, exponential function*

INTRODUCTION

Exponents are one of the fundamental topics that students must understand in mathematics. However, students still experience difficulties when learning exponents (Cangelosi et al., 2013; Sastre & Mullet, 1998; Sumirat et al., 2023; Winarti, 2016). Problems related to bases and powers of exponents in non-natural numbers are still being found (Avcu, 2014; Iymen & Duatepe-Paksu, 2015; Kontorovich, 2016; Levenson, 2012; Suarka & Kusumah, 2024). Ulusoy (2019) identified four major obstacles in learning exponents: difficulties understanding exponents as repeated multiplication, zero exponents, negative exponents, and performing operations involving exponents. These learning challenges are particularly concerning given that the mathematics curriculum explicitly requires

students to master exponent concepts and apply them in solving real-world problems.

These conceptual challenges may stem from how exponents are introduced in classrooms. Typically, exponents are first presented as repeated multiplication, which students can grasp easily when both the base and the exponent are natural numbers. However, when students encounter negative, zero, or rational exponents, this understanding becomes harder to generalise. Several studies consistently indicate that students are more successful in solving exponent problems when dealing with natural numbers (Avcu, 2014; Iymen & Duatepe-Paksu, 2015; Ulusoy, 2019). To address these difficulties, it is crucial to consider the role of learning resources, particularly textbooks, which can either support or hinder students' conceptual understanding.

In this regard, textbooks play a crucial role in shaping how mathematics is taught and understood, especially in Indonesia, where 93% of teachers report relying on textbooks (Human Development Department, East Asia and Pacific Region, 2010). Furthermore, TIMSS researchers say over 70% of teachers rely on textbooks as their primary teaching resources (Mullis et al., 2012). Given the significant reliance on textbooks, it is essential to ensure the quality of their content through comprehensive research. The use of appropriate and varied media creates student enthusiasm for learning (Munawir et al., 2024; Salsabila et al., 2022; Suprihatin & Manik, 2020; Susanti, 2020; Warkintin & Mulyadi, 2018; Wisnu Kartika et al., 2021).

Several studies have been conducted on textbook analysis, focusing on various aspects of mathematical content. For instance, Stylianides & Stylianides (2008) examined the presence of reasoning-and-proving tasks in mathematics textbooks. Meanwhile, a study by Wijaya et al. (2015) revealed that only about 10% of tasks in Indonesian textbooks were context-based. However, despite these efforts, research analysing textbooks at the senior high school level in Indonesia remains limited.

Previous studies on mathematics textbook analysis in Indonesia have predominantly focused on the lower secondary level. For instance, Kusumawati

(2023) analysed the Grade VIII mathematics textbook regarding the scientific approach and authentic assessment. Similarly, Siscasari et al. (2021) examined the content of Grade VIII textbooks based on the scientific approach. In contrast, research targeting senior high school mathematics textbooks is relatively limited. Arroida (2018) assessed the quality of a Grade X mathematics textbook concerning content, language, presentation, and graphics. However, specific studies focusing on the presentation of exponent concepts in senior high school textbooks remain scarce.

This gap highlights the need to investigate further how mathematics textbooks structure and present the concept of exponents and exponential functions. By employing the Reference Epistemological Model (REM) as an analytical framework, this study views exponents as computational tools and mathematical objects developed through institutionalisation and abstraction. In scholarly mathematics, exponents are embedded within broader conceptual structures, such as exponential functions $f(x) = a^x$Exponential growth and its inverse relationship with logarithms. In contrast, at the school level, exponents are frequently introduced as a set of operational rules to be memorised, with limited attention to reasoning or theoretical justification.

Against this backdrop, the present study aims to analyse how exponential functions are learned through Indonesian mathematics textbooks, using a praxeological approach that focuses on the organisation of content and the relationship between technical and theoretical components of exponent learning. This analysis seeks to better understand how current teaching materials facilitate students' understanding of the exponent concept and offer insights that support the development of more meaningful and contextually relevant instructional materials.

RESEARCH METHOD

The research method used is qualitative research with content analysis. Content analysis of textbooks involves an analysis of the content and activities presented in the textbooks. According to Zhuchdi & Afifah (2019), content analysis always involves connecting or comparing findings with several criteria or theories.

The theory used for analysing textbooks is the theory of praxeology. According to Chevallard et al. (2022), praxeology has four components, namely, the first type of task is the task presented in the textbook. The second is technique, namely, the consequences and orders of what can be done based on the type of task. The third is technology related to the motives or reasons behind the technique by the author of the textbook. The last is theory which is a way of justifying the technology that will lead to applying more abstract knowledge. At this stage will be analyzed whether the type of assignment is under the theory. We used a textbook that was used by teachers of 10th-grade students published by the Ministry of Education, Culture, Research and Technology. On the theory of exponent, there are (at least) four categories that we can focus on. The definition of exponent numbers, properties of exponent numbers, exponential function, and root forms. However, because this research focuses on exponential material, the material studied is limited to only the definition of exponent numbers, properties of exponent numbers, and exponential functions.

Education System Background

The Ministry of Education, Culture, Research, and Technology provides the Merdeka Curriculum in Indonesia as a development of the 2013 Curriculum. The structure of the Independent Curriculum organizes learning into six sequential phases, namely Phase A, Phase B, Phase C, Phase D, Phase E, and Phase F (Ministry of Education, Culture, Research, 2022), which correspond to six years of elementary school (for students aged 7-12), three years of lower secondary school (for students aged 13-15), and three years of upper secondary school (for students aged 16-18). A wide range of publishers and government agencies provide textbooks in Indonesia. In Indonesia, the choice of books used depends on the choice of each school and teacher, but most schools still use books published by government agencies as one of the books used.

Data Collection

This investigation collected initial data from a 10th-grade mathematics textbook published by the Ministry of Education, Culture, Research, and Technology, which aligns with the Merdeka Curriculum. Although several versions

of textbooks are available from different publishers, they follow the same learning objectives outlined in the national curriculum. This textbook was the primary source for identifying the four components of praxeology: task, technique, technology, and theory.

In analysing the logos aspect of the textbook, which encompasses its technological and theoretical components, a focus group discussion was conducted with mathematics experts and educators for approximately one hour to mitigate potential researcher bias in interpretation. This discussion aimed to understand their perspectives on the suitability of each task concerning its content, context, and the logical interconnection between tasks. Furthermore, the discussion explored observations regarding the techniques presented, the depiction of technological discourse (explicit or implicit) compared to mathematicians' conceptualisation of exponents, and how the textbook facilitates the integration of task, technique, and technology to foster a comprehensive understanding of exponents in students.

This group discussion involving mathematics experts and educators lasted approximately one hour. The discussion was guided by questions designed to elicit insights from the participants. These questions included inquiries such as: How do experts and teachers perceive the suitability of each task concerning its content, context, and the interconnection between tasks? What are the observations regarding the techniques presented in the textbook? How is the technological discourse, whether explicit or implicit, depicted in the textbook compared to the conceptualisation of the exponent concept by mathematicians? Furthermore, in what ways does the textbook facilitate the integration of task-technique-technology to assist students in developing a comprehensive understanding of exponents?

Data Analysis

The data analysis process in this research consists of two main phases, namely the praxis block analysis phase and the logos block analysis phase. At the praxis block analysis phase, the researcher focused on examining the praxis elements in the textbook, including tasks and techniques. Next, the analysis continues by exploring the theoretical aspects of this textbook, including technology and theory, through the logos block analysis phase.

These researchers aim to categorise various tasks related to exponential material and exponential functions presented in textbooks. Based on the results of the initial analysis, four different materials in the textbook were used, including the definition of exponents, properties of exponents, exponential functions, and root forms. Some of the material presented is re-elaborated into several newer sections. This textbook covers various topics that are important to study.

Furthermore, in understanding the exponent material in each sub-material, the problems guide students to understand the material presented. Each task type contains two types of problems: examples and exercises. Example problems are created to illustrate the concept being studied, and solutions are provided to explain how the problem should be solved. Meanwhile, exercise problems are designed to allow students to apply the knowledge they have received through example problems. In this research, the problem that will be studied further is the example problem because this type of task is an important part of the student learning process.

After reviewing the praxis block, the analysis continues to the logos block analysis phase, which provides explanations, justifications, and rationales for the existing task techniques. This analysis examined the textbook's definitions, examples, and properties related to exponents and function exponents. The analysis aimed to uncover the theoretical discourse employed to facilitate students' comprehension of exponents and exponent functions and evaluate the coherence in organising these theoretical elements within the textbook.

FINDINGS AND DISCUSSION

Findings

Based on the textbook used, this research focuses on examining four task types, denoted as $T_1$to T_4. This task is important to analyse because these four tasks are essential for understanding exponential numbers and exponential functions through the activities presented. Table 1 presents the textbook's four types of tasks and their respective tasks. Furthermore, task type 1 (T_1) consists of task 1, which is symbolised as t_1.

In addition, in Table 1, four main tasks or objectives are presented and categorised into four different types to help students construct their understanding of the concept of exponents and exponent functions. At t_1, t_3, t_4 present assignments whose context is close to everyday life, while t_2 presents assignments consisting of several questions, hoping students can draw information from these questions.

Table 1. Types of Tasks and Tasks for Introducing Exponent and Exponent Function

Type of Task (T)	**Task (t)**
$\mathbf{T_1}$: to define an exponent as repeated multiplication	$\boldsymbol{t_1}$: A person carrying the virus enters area A. After being observed, the person carrying the virus had infected two other people. In the next phase, the two infected people also infected two others. In the next phase, four people in the previous phase also infected two other people each. This pattern of transmission continues, where no one is infected twice. 1. Complete the table below, which will give you an overview of virus transmission in each phase up to phase 8. Transmission phase | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 People are infected | 2 | 4 | 8 | … | … | … | … | … 2. How many people were infected by the virus in phase 10? How do you know? 3. If the number of phases is n, how can we represent the number of people infected in the nth phase? How do you know?
$\mathbf{T_2}$: to identify the characteristics of an exponent	$\boldsymbol{t_2}$: Look at the table showing the exponent form 2^n Below.

2^n	Results
2^1	2
2^2	4
2^3	8
2^4	16
2^5	32
2^6	64
2^7	128
2^8	256
2^9	512
2^{10}	1024

Now, try to observe the exponential form below. Complete and discuss with your group friends.

1) $2^2 \bullet 2^3$	4) $\frac{2^8}{6^6}$	7) $(2^3)^3$
2) $2^5 \bullet 2^2$	5) $\frac{2^{10}}{6^3}$	8) $(2^4)^2$
3) $2^3 \bullet 2^7$	6) $\frac{2^6}{6^4}$	9) $(2^2)^5$

Based on the observations above, what can you conclude from the properties of these exponents?

1. In general, what are the other forms of $a^m \cdot a^n$?

2. In general, what are the other forms of $\frac{a^m}{a^n}$?

3. In general, what are the other forms of $(a^m)^n$?

$\mathbf{T_3}$: to define the exponential function	$\boldsymbol{t_3}$: Someone carried the virus and infected three other people. In the next phase, each person infects three other people. 1. How many people will be infected in each subsequent phase? 2. How many people will be infected with the virus in the 20^{th} phase? 3. What function best describes the transmission?
$\mathbf{T_4}$: to represent an exponential function exponent with a curve	$\boldsymbol{t_4}$: Which of the following function graphs represents an increase in the number of people infected with the virus if the continuous transmission occurs? Why is that?

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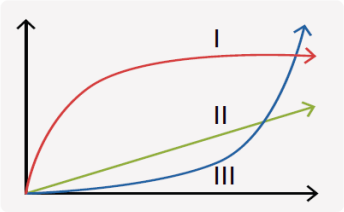

This research examined the strategies presented in the textbook for completing each task to identify the techniques used. As a general idea, textbooks explicitly outline techniques for each type of task. Furthermore, this research was conducted to evaluate the techniques' effectiveness. Detailed findings regarding techniques for each type of task will be explained in Table 2.

Table 2. Techniques for Task Types Relating to Exponent and Exponent Function

Type of Task (T)	Technique (τ)	Description of Technique
$\mathbf{T_1}$	Numerical, symbolic, and formal	$\boldsymbol{\tau_1}$: 1. The following table has been completed. 2. The number of people infected in the 10th phase is 1,024. The pattern of transmission is 2^n So, to get the number of people infected in the 10^{th} phase is $2^{10} = 1.024$. Alternatively, multiply the number in the previous phase by 2, or say they will multiply 2 ten times, because they will look for the number of people infected in the 10^{th} phase. 3. The relationship between the transmission phase and the number of people infected with the virus is to get the number of people infected in the nth phase, so the pattern used is 2^n Where n is the transmission phase.
$\mathbf{T_2}$	Numerical and formal	$\boldsymbol{\tau_2}$: 1. $2^2 \cdot 2^3 = 4 \times 8 = 32 = 2^5$ 2. $2^5 \cdot 2^2 = 32 \times 4 = 128 = 2^7$ 3. $2^3 \cdot 2^7 = 8 \times 128 = 1024 = 2^{10}$ 4. $\frac{2^8}{2^6} = \frac{256}{64} = 4 = 2^2$

Transmission Phase	1	2	3	4	5	6	7	8
Number of Infected People	2	4	8	16	32	64	128	256

Transmission Phase	1	2	3	4	5	6	7	8
Number of Infected People	2	$4 = 2 \times 2$	$8 = 4 \times 2 = 2 \times 2 \times 2$	$16 = 8 \times 2 = 2 \times 2 \times 2 \times 2$	$32 = 16 \times 2 = 2 \times 2 \times 2 \times 2 \times 2$	$64 = 32 \times 2 = 2 \times 2 \times 2 \times 2 \times 2 \times 2$	$128 = 64 \times 2 = 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2$	$256 = 128 \times 2 = 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2$

		5. $\frac{2^{10}}{2^3} = \frac{1024}{8} = 128 = 2^7$ 6. $\frac{2^6}{2^4} = \frac{64}{16} = 4 = 2^2$ 7. $(2^3)^3 = (8)^3 = 512 = 2^9$ 8. $(2^4)^2 = (16)^2 = 256 = 2^8$ 9. $(2^2)^5 = (4)^5 = 1024 = 2^{10}$ From the above exploration, it can be concluded that: 1. $a^m \cdot a^n = a^{m+n}$ 2. $\frac{a^m}{a^n} = a^{m-n}$ 3. $(a^m)^n = a^{m \times n}$
$\mathbf{T_3}$	Numerical, symbolic, and formal	$\boldsymbol{\tau_3}$: 1. People who will be infected in each subsequent phase are presented in the following table.

Transmission Phase	1	2	3	4	5	6	7	8
Number of Infected People	3	9	27	81	243	729	2.187	6.561

From this data, it appears that many people are infected with the virus in each phase (n), forming a pattern. Let N be the number of people infected with the virus in each phase, because $N = 3^n$.

2. The number of people infected in the 20th phase is $N = 3^{20} = 3.486.784.401$.
3. The function that correctly describes the transmission of the virus is the exponential function.

$\mathbf{T_4}$	Graphic	$\boldsymbol{\tau_4}$: From this graph, it can be seen that graph number III represents the increase in the number of people infected with the virus if the transmission process occurs continuously. If you pay attention to the increase in cases in each phase (table in part a), the number of people infected with the virus is quite significant, so Graph III best describes this condition.

The techniques used in several tasks range from visuospatial and formal to numerical and symbolic approaches (Tall, 1996). The formal technique emphasises exponent as repeated multiplication, exemplified in $\boldsymbol{\tau_1}$ part 1, $\boldsymbol{\tau_2}$, and $\boldsymbol{\tau_3}$ part 1. The numerical technique engages students to do numerical calculations, as manifested in $\boldsymbol{\tau_1}$ part 2, $\boldsymbol{\tau_2}$, and $\boldsymbol{\tau_3}$ part 2. Finally, symbolic techniques come into play when tasks involve exponent function through algebraic formulas $f(x) = ka^x$ as in $\boldsymbol{\tau_1}$ part 3 and $\boldsymbol{\tau_3}$ part 1. In general, the textbooks analyzed mostly use numerical and formal techniques.

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***Logos* Block**

Furthermore, the analysis continues with the logo block. In the textbook, this study identifies two technological discourses related to exponents and exponential functions, then organises the praxis blocks into two local praxeologies $\boldsymbol{T_1}$ part 1 and part 2, $\boldsymbol{T_2}, \boldsymbol{T_3}$ part 1 and 2 align cohesively in a shared technological discourse (θ_1). The first praxeologists defined exponents as repeated multiplication. Meanwhile, $\boldsymbol{T_3}$ part 1 and part 3 and $\boldsymbol{T_4}$ constitute a shared technological discourse relating to exponential functions (θ_2). More details regarding each technology are explained in Table 3.

Table 3. Comparison between Textbook and Formal Definition of Each Technology (θ)

Technology (θ)	Textbook's definition	Formal definition
θ_1 : the definition of exponential	If a is a real number and n is a positive integer, then a^n represents the product of the number a by n factors and is written as $a^n = \underbrace{a \times a \times a \times \ldots \times a}_{\text{n factor}}$	If a is a real number or $a \in \mathbb{R}$ and n is an integer positive, then $a^n = a.a.a.a \ldots . a$ a is called the base, and n is the power.
θ_2: Exponential function	An exponential function is expressed by $f(x) = n \times a^x$ Where a is a base, $a > 0, a \neq 1$, n is a nonzero real number, and x is the distribution of real numbers.	Exponential functions are functions that have a general form $f(x) = ka^x$ with k and a is a constant, $a > 0, a \neq 1$ Symbolically, the exponential function can be written in the following form. $f = \{(x, y)/y = ka^x, a > 0, a \neq 1\}$

Based on the results of the analysis of definitions contained in textbooks and formal definitions, it was found that there was no significant difference between the definitions of exponential and exponential functions contained in books and formal definitions. It shows that the textbook has presented proper concepts for students.

Discussion

Based on the results of the praxeological analysis, the researcher compared the praxeological organisation of textbooks and preliminary studies on exponents and exponential functions. This research focuses on understanding how this structured textbook can influence students' understanding and provide valuable insights that can contribute to a new praxeological organisation for introducing exponents and exponential functions.

When introducing exponents and exponential functions, this textbook combines two local praxeologies. This praxeology is said to be "locals" considering that their task types and techniques share discourses from two distinct technologies (θ) (Bosch & Gascón, 2014). A single theory (Θ) substantiates these two technologies, specifically the theory of exponent.

The local praxeological organisation of functions by illustrating examples as pairings between sets $P_1 = \{(T_1, T_2)/(\tau_1, \tau_2)/\theta_1/\Theta\}$. Based on the results of discussions with experts, local praxeology requires several modifications to enhance this organisational approach. As stated in Table 2, T_1 consists of a task $\tau_1$which aims to help students understand the definition of exponents as repeated multiplication. If you look at the arrangement of questions contained in τ_1, it is similar to the arrangement in τ_3, as a note, task τ_3 aims to help students understand the definition of the exponential function. Insights from experts suggest that task τ_1 should be able to serve as a more effective introduction since it has not yet discussed the exponential function, it is better to focus on asking questions related to the definition of exponents as repeated multiplication, for example, by simply asking questions τ_1 part 1 and 2.

Moreover, there are no issues found for T_2. The approach used in T_2 is an inductive approach by giving students several examples first, before students are asked to conclude from these examples. Learning involving inductive thinking patterns provides students with opportunities to understand concepts or obtain generalisations more meaningfully (Rochmad, 2007).

Furthermore, this study analysed the fourth task technique, explicitly grounded in the properties of an exponential function (θ_2), leading to the

identification of the type of technique of the second local praxeology $P_2 = \{(T_3, T_4)/(\tau_3, \tau_4)/\theta_2/\Theta\}$. For the type of task T_3 which consists of τ_3, it is arranged to help students understand the exponential function. The suggestions given by the experts have been presented in the previous paragraph. In addition, the type of exponential function displayed can be more varied by displaying the function in the form $f(x) = ka^x,\ k \neq 1$, so it is potentially challenging for students to grasp. Furthermore, for the type of task T_4 which consists of τ_4Get suggestions from experts by asking questions that allow students to form the exponential function graphs, and not just choose which graph is suitable from the questions given.

This review of task techniques naturally leads to a deeper reflection on students' cognitive engagement during the learning process. Although the textbook presents a variety of task types and techniques, the findings indicate that most tasks are procedural and repetitive, thereby placing students at a lower level of cognitive engagement, such as recalling and understanding, without fostering exploration or reflective reasoning. Notably, the theory component (Θ) is not yet fully aligned with constructivist theory, which emphasises that students construct knowledge based on their experiences (Prameswari et al., 2024). This misalignment suggests that the cognitive demand of the tasks has not been optimally designed to support the development of higher-order thinking skills (HOTS), such as analysing, evaluating, or generating alternative solutions. For instance, the task involving exponential function graphs only requires students to choose an appropriate graph rather than interpret data or build graphs based on given information. Tasks should activate students' critical and conceptual thinking processes to foster deeper learning. This concern is echoed by Utami et al. (2024), who noted that this limitation guides students towards imitation rather than fostering active engagement in developing problem-solving strategies, indicating a tendency for students to mimic techniques without truly understanding the underlying concepts. Furthermore, they emphasised that the textbook's approach risks promoting rote memorisation of problem-solving procedures at the expense of deep conceptual understanding.

This limitation in promoting cognitive engagement is also closely related to the incomplete integration of praxeological components in the textbook structure.

Although the textbook presents types of tasks, techniques, technologies, and theories, the systemic interconnection among these components remains underdeveloped. The textbook does not explicitly demonstrate how techniques are grounded in their underlying technological reasoning and justified by theoretical foundations. This aligns with the findings of Utami et al. (2024), who stated that the theoretical dimension of praxeology tends to remain implicit within textbooks, suggesting a lack of emphasis on how and why techniques are applied in mathematical problem solving. Consequently, definitions, properties, and examples are predominantly presented as memorisation lists, lacking an emphasis on cultivating the technological-theoretical foundations. As a result, the learning process may lack coherence in linking procedural practices to conceptual understanding. Strengthening the integration of praxeological components is crucial to constructing a more comprehensive and reflective learning trajectory for students.

CONCLUSION

In conclusion, this study analysed the concept of function in the Indonesia 10^{th}-grade student textbook, employing the notion of praxeology. Based on the *praxis* block analysis, T_1 addressing the definition of exponent, T_2 focusing on the characteristics of the exponent, T_3 define the exponential function, and T_4 discuss about the graphic of an exponential function. The textbook presents almost all techniques for each task type, and usually only has one solution method. On the other hand, the logo block leads to two significant results. The first technology (θ_1), the definition of exponential is repeated multiplication. The second technology (θ_2) discusses exponential function with analytical expression denoted by $f(x) = n \times a^x;\ a > 0, a \neq 1$. A general theory, namely exponential, justifies all technological discourses (Θ).

This research has limitations, including the fact that this research only takes three of the four materials in the exponential chapter. The root form material presented in the exponent's chapter is not shown because the chapter does not have much to do with exponents and extends to logarithm material. Hence, the

researchers decided to limit the material analysed.

Not only were textbooks using praxeology, but the analysis results carried out in this research were also discussed with experts to obtain additional views, so the resulting writing has richer information. The textbooks analysed are quite suitable for use in the learning process. However, several notes have been given to improve this textbook based on the analysis results and discussions with experts.

Future researchers interested in similar topics can develop their research to a wider scope, for example, by expanding the topic being analysed or using other books that the government does not publish as objects of analysis.

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