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Conceptual Representation of the Homogeneity of Variance Test in Educational Statistics Textbooks and Its Potential to Cause Misconceptions

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ABSTRACT

Textbooks play an important role in shaping students' understanding of statistical concepts. However, when conceptual representations emphasize procedural aspects rather than conceptual understanding, they may contribute to misconceptions. This study aims to analyze how the concept of the homogeneity of variance test is represented in educational statistics textbooks and to identify the potential misconceptions arising from these representations. The study employed a descriptive qualitative approach using document analysis. The data consisted of ten educational statistics and statistics-for-educational-research textbooks that are widely used in teacher education programs in Indonesia. Data were collected through document review and analyzed using qualitative content analysis, focusing on definitional, procedural, and conceptual representations, as well as potential misconceptions. The findings indicate that all textbooks present the F-test procedure by dividing the larger variance by the smaller variance. However, only a few textbooks explain the underlying concept of the F distribution, the rationale for placing the larger variance in the numerator, and the relationship between the F distribution and statistical decision-making. The dominance of procedural representations may lead students to the misconception that the larger variance must always be placed in the numerator and that the F statistic can never be less than one. These findings suggest that the current representation of the homogeneity of variance test in educational statistics textbooks does not adequately support the development of students' conceptual understanding. Therefore, a more balanced presentation integrating both procedural and conceptual aspects is needed to minimize potential misconceptions in statistics education.

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1. INTRODUCTION

Statistics is one of the fundamental courses that plays an essential role in equipping university students, particularly prospective teachers and educational researchers, with the ability to understand, analyze, and interpret data scientifically (Syahrial et al., 2025). One of the statistical procedures widely applied in educational research is the homogeneity of variance test, which is commonly conducted before performing parametric tests such as the independent-samples *t*-test and analysis of variance (ANOVA). Therefore, a sound understanding of the concept of homogeneity of variance is an important prerequisite for students to conduct appropriate data analysis and draw valid research conclusions.

In statistics education, textbooks remain one of the primary learning resources used by both lecturers and students (Anggraini & Syahbrudin, 2021; Nu'man, 2019). Beyond serving as sources of information, textbooks shape students' ways of thinking and influence their conceptual understanding of statistical concepts (Amirulmukminin & Purnama, 2023). Consequently, the way concepts are represented in textbooks deserves careful attention because it affects how students understand statistical procedures, formulas, and the underlying meanings of statistical methods.

A common representation found in many educational statistics textbooks presents the homogeneity of variance test by calculating the ratio of the larger variance to the smaller variance, ensuring that the resulting F statistic is always greater than or equal to one (Sulistiyowati, 2017; Usmadi, 2020). From a practical perspective, this presentation simplifies the use of the F-distribution table, which typically provides critical values only for the right tail of the distribution. However, this procedural simplification may lead students to believe that the larger variance must always be placed in the numerator and that the F statistic can never be less than one. Conceptually, however, the F distribution is defined as the ratio of two variances without requiring the larger variance to appear in the numerator. As a result, students may gradually shift from understanding the underlying statistical concept to merely memorizing procedural rules.

This phenomenon is frequently observed in statistics courses at the university level. Students are generally able to follow computational procedures demonstrated in textbooks but often encounter difficulties when faced with situations that differ from the standard examples. This condition suggests the possibility of misconceptions originating from the way concepts are represented in instructional materials. In the context of mathematics and statistics education, misconceptions not only hinder students' current understanding but may also affect their future ability to teach and apply statistical concepts appropriately.

Previous studies have examined the quality of mathematics and statistics textbooks from various perspectives, including conceptual accuracy, curriculum alignment, mathematical representations, and readability (Hidayat & Usodo, 2023;

Setiawan, 2019). Other studies have investigated students' misconceptions in statistics, covering topics such as probability, statistical inference, and the interpretation of data analysis results (Afnenda et al., 2023; Aisyah et al., 2026; Arifin & Aprisal, 2020). Nevertheless, studies specifically examining how the concept of the homogeneity of variance test is represented in educational statistics textbooks and how such representations may contribute to misconceptions remain limited. Most existing research focuses on students' learning outcomes or errors without exploring the conceptual sources of these misconceptions embedded in textbook presentations.

Based on this situation, there remains a research gap regarding how the representation of the homogeneity of variance concept in educational statistics textbooks may contribute to the development of inaccurate conceptual understanding. Identifying misconceptions originating from textbook representations is essential for improving the quality of instructional materials and enhancing statistics education.

The novelty of this study lies in its specific focus on analyzing the representation of the homogeneity of variance test in educational statistics textbooks widely used in higher education, particularly the presentation of variance ratios in the F-test and its implications for the emergence of conceptual misconceptions. Unlike previous studies that primarily examined students' errors or evaluated textbook quality in general, this study explicitly links the characteristics of textbook representations to the potential development of procedural understanding that is inconsistent with the underlying statistical concepts.

Accordingly, this study aims to analyze how the concept of the homogeneity of variance test is represented in educational statistics textbooks and to identify the potential misconceptions that may arise from these representations. The findings are expected to contribute to the development of statistics textbooks that better promote conceptual understanding and to provide insights for lecturers in designing statistics instruction that minimizes students' misconceptions.

2. METHOD

This study employed a descriptive qualitative approach using document analysis. This approach was chosen because the study aimed to examine how the concept of the homogeneity of variance test is represented in educational statistics textbooks and to identify the potential misconceptions that may arise from these representations. Document analysis enabled a systematic examination of textbook content as the primary data source to obtain an in-depth understanding of how statistical concepts are presented in the teaching and learning process.

The data sources consisted of Indonesian-language educational statistics textbooks that are widely used in teacher education programs at higher education

institutions. The textbooks were selected purposively based on the following criteria: (1) they include a discussion of the homogeneity of variance test using the F distribution; (2) they are published by academic publishers whose books are commonly used as references in educational statistics courses; and (3) they are currently used or recommended in undergraduate teacher education programs. Based on these criteria, the textbooks that met the requirements were selected for analysis.

The unit of analysis comprised the sections of each textbook discussing the homogeneity of variance test, including the definition of the F-test, the statistical formula, computational procedures, worked examples, interpretation of results, and the accompanying conceptual explanations. The analysis focused on identifying how textbook authors represented the relationship between the F distribution and the homogeneity of variance test.

Data were collected through document review. All sections related to the homogeneity of variance test were examined thoroughly and documented using an analysis protocol developed by the researchers. The collected data included the presentation of formulas, conceptual explanations, procedural steps, illustrative examples, and explanations of why the larger variance is placed in the numerator when calculating the F statistic.

The data were analyzed using qualitative content analysis. The first stage involved identifying and coding the conceptual representations found in each textbook. In the second stage, the codes were classified into four analytical categories: (1) **definitional representation**, referring to the definition and meaning of the F distribution; (2) **procedural representation**, referring to the computational procedures of the homogeneity of variance test; (3) **conceptual representation**, referring to explanations linking the computational procedures to the underlying statistical concepts; and (4) **potential misconceptions**, referring to representations that may lead students to develop understandings inconsistent with the actual statistical concepts. The final stage involved interpreting the findings to identify dominant patterns of representation and the potential misconceptions arising from the presentation of the material.

To enhance the credibility of the findings, researcher triangulation (*peer debriefing*) was conducted. The coding and categorization results were discussed with lecturers and researchers specializing in statistics and mathematics education. In addition, the analysis was performed iteratively by comparing findings across textbooks to ensure consistent and trustworthy interpretations.

The findings are presented descriptively through narrative explanations, tables, and representative excerpts from the analyzed textbooks. This presentation is intended to illustrate the characteristics of the conceptual representations of the homogeneity of variance test in educational statistics textbooks and to explain the potential misconceptions that may result from these representations. Through this

approach, the study provides a comprehensive description of the quality of the presentation of the homogeneity of variance test in educational statistics textbooks used in higher education.

3. RESULTS AND DISCUSSION

Characteristics of the Analyzed Textbooks

This study analyzed ten educational statistics and statistics-for-educational-research textbooks that are widely used in teacher education programs in Indonesia. The textbooks were selected based on the following criteria: they include a discussion of the homogeneity of variance test using the F distribution, are published by academic publishers commonly used as references in statistics courses, and are currently used in undergraduate teacher education programs.

Table 1. Textbooks Included in the Analysis

No	Book Title	Author
1	Statistik Penelitian Pendidikan	Gito Supriadi
2	Statistik Pendidikan	Yanuar Kiram Hanief & Wasis Himawanto
3	Statistika Pendidikan	F. Irawan dkk.
4	Statistika Pendidikan: Teori dan Aplikasi	Tim Penulis
5	Statistika Pendidikan: Aplikasi SPSS dan Excel	Hermansah
6	Pengantar Statistik Pendidikan	Anas Sudijono
7	Statistika untuk Penelitian	Sugiyono
8	Dasar-Dasar Statistika	Agus Irianto
9	Statistik untuk Penelitian Pendidikan	Riduwan
10	Statistik	Sutrisno Hadi

All ten textbooks discuss the homogeneity of variance test as one of the prerequisite tests for parametric statistical analysis. However, considerable variation was found in how the concept, computational procedures, and theoretical explanations were presented.

3.2 Representation of the Definition of the Homogeneity of Variance Test

The analysis showed that all textbooks define the homogeneity of variance test as a procedure for determining whether the variances of two or more groups are equal before conducting parametric statistical analyses. Nevertheless, the depth of explanation regarding the concept of the F distribution varies substantially across the textbooks.

Table 2. Representation of the Definition and Concept of the F Distribution

Aspect Analyzed	Number of Textbooks
Explains the purpose of the homogeneity of variance test	10
Explains the F distribution as the ratio of two variances	3
Explains the properties of the F distribution	1
Explains the relationship between the F distribution and statistical decision-making	4

As shown in table 2, most textbooks emphasize the purpose of the homogeneity of variance test rather than providing a conceptual explanation of the F distribution as its theoretical foundation.

Procedural Representation of the Homogeneity of Variance Test

The analysis revealed that all textbooks present almost identical computational procedures. The first step consistently instructs readers to identify the larger and smaller variances, after which the F statistic is calculated by dividing the larger variance by the smaller variance.

Tabel 3. Representasi Prosedural Uji Homogenitas Varians

Aspect Analyzed	Number of Textbooks
Uses the formula *F = Larger Variance / Smaller Variance*	10
Provides detailed computational procedures	10
Includes numerical worked examples	10
Explains the rationale for placing the larger variance in the numerator	2
Explains alternative ways of constructing the variance ratio	0

These findings indicate a strong emphasis on procedural representation in the presentation of the homogeneity of variance test.

Identification of Potential Misconceptions

A further analysis was conducted to identify potential misconceptions arising from the representations found in the textbooks. A representation was considered to have the potential to generate misconceptions when a procedure was presented without sufficient conceptual explanation or when procedural rules could be interpreted as conceptual definitions.

The most prevalent potential misconception is the belief that the larger variance must always be placed in the numerator. This finding reflects the fact that most textbooks present only a single computational procedure without explaining the mathematical rationale or the underlying properties of the F distribution.

Tabel 4. Potensi Miskonsepsi yang Teridentifikasi

Potential Misconception	Number of Textbooks
The larger variance must always be placed in the numerator	8
The F statistic cannot be less than one	9
The F-test is merely a computational procedure	7
The F distribution is equivalent to a particular formula	6

General Patterns of Concept Representation

Overall, a relatively consistent pattern was observed across the analyzed textbooks. Most textbooks begin by explaining the purpose of the homogeneity of variance test, followed by the computational formula, worked examples, and statistical decision-making procedures. In contrast, explanations of the concept of the F distribution, the rationale for using a particular variance ratio, and alternative representations are rarely provided. Consequently, the representation of the homogeneity of variance test in these textbooks places considerably greater emphasis on procedural aspects than on conceptual understanding.

3.1. Discussion

The findings indicate that the representation of the homogeneity of variance test in educational statistics textbooks is still predominantly procedural. All textbooks analyzed present the computational procedure by calculating the ratio of the larger variance to the smaller variance, whereas explanations of the F distribution as the theoretical foundation of the test are relatively limited. This finding suggests that textbooks place greater emphasis on computational techniques than on helping students develop a conceptual understanding of the statistical principles underlying the procedure.

The predominance of procedural representations found in this study is consistent with previous textbook analyses in mathematics and statistics education, which have shown that instructional materials tend to prioritize algorithmic competence over conceptual understanding. In statistics education, a procedural orientation can indeed help students solve problems efficiently and systematically. However, when procedures are presented without adequate conceptual explanations, students are likely to develop a mechanical understanding that is limited to situations similar to the examples provided. Consequently, they may be able to perform calculations correctly but struggle to explain the statistical rationale underlying those procedures.

One of the most important findings of this study is the consistent use of the F-test formula in which the larger variance is placed in the numerator and the smaller

variance in the denominator. Statistically, this procedure does not constitute the definition of the F distribution; rather, it is a practical strategy designed to ensure that the calculated F statistic is greater than or equal to one, thereby facilitating the use of conventional F-distribution tables. Nevertheless, only a small number of textbooks explain the rationale behind this procedure. Most textbooks simply present the formula and worked examples without discussing the mathematical reasoning that justifies this convention.

This finding can be interpreted through the **Concept Image** and **Concept Definition** framework proposed by David Tall and Shlomo Vinner. According to this theory, an individual's understanding of a mathematical concept consists of two complementary components: *concept definition* and *concept image*. A *concept definition* refers to the formally accepted mathematical definition, whereas a *concept image* refers to the mental representation developed through learning experiences, examples, and instructional representations. In the context of this study, the formal definition of the F distribution is a probability distribution derived from the ratio of two variances. However, the dominant representation found in the textbooks may lead students to construct the concept image that the F statistic is always obtained by dividing the larger variance by the smaller variance. When students' concept images differ from the formal concept definition, misconceptions are likely to emerge.

The potential for misconception is further reflected in the finding that most textbooks do not discuss alternative forms of constructing the variance ratio. As a result, students may conclude that the larger variance must always be placed in the numerator. From a theoretical perspective, however, the F distribution does not require either variance to occupy a specific position in the ratio. Placing the larger variance in the numerator is merely a convention adopted to simplify the interpretation of hypothesis-testing results. When this convention is mistakenly interpreted as part of the conceptual definition, students may develop an incomplete understanding of the statistical meaning of the F distribution.

Another noteworthy finding is the absence of discussions concerning F statistics that are less than one. All examples and exercises presented in the analyzed textbooks produce F values greater than or equal to one. Consequently, students may develop the misconception that F values below one are impossible. From the perspective of conceptual learning, this finding indicates that students are exposed to only one representation of the concept, thereby limiting opportunities to develop a broader and more flexible understanding of the F distribution.

This phenomenon is consistent with previous studies in statistics education suggesting that misconceptions often arise from excessive simplification of concepts during instruction. In many cases, pedagogical strategies originally intended to facilitate learning may inadvertently promote incomplete understanding when they are not accompanied by adequate conceptual explanations. In other words,

procedural simplifications may be beneficial during the early stages of learning but may hinder the development of statistical reasoning if they become the sole representation of the concept.

Beyond misconceptions concerning the form of the F statistic, the predominance of procedural representations also influences students' understanding of the purpose of the homogeneity of variance test. Most textbooks explain how to calculate the F statistic and compare it with the critical value from the F table, yet they provide little explanation of why comparing two variances serves as a basis for assessing variance homogeneity. Consequently, students may perceive the homogeneity of variance test merely as a sequence of computational steps rather than as a statistical procedure grounded in relationships among data variability, probability distributions, and statistical decision-making. This finding suggests that the conceptual representations provided in current textbooks do not fully support the development of statistical reasoning, which is one of the primary objectives of statistics education.

The findings also indicate that potential misconceptions do not necessarily originate from incorrect statistical content. Instead, they arise from an imbalance between procedural and conceptual representations. Overall, the textbooks analyzed present mathematically correct computational procedures. However, the limited explanation of the reasoning behind those procedures may encourage students to develop a narrow understanding of the F distribution and the homogeneity of variance test.

These findings have important implications for the development of educational statistics textbooks. Textbooks should be designed not only to develop computational proficiency but also to foster conceptual understanding. Authors should provide more explicit explanations of the meaning of the F distribution, the rationale for placing the larger variance in the numerator, the possibility of obtaining F values less than one, and the relationship between the F distribution and hypothesis testing. Likewise, statistics instructors should complement textbook explanations with conceptual discussions so that students understand not only how to perform statistical procedures but also why those procedures are valid.

Overall, the findings demonstrate that the representation of the homogeneity of variance test in educational statistics textbooks emphasizes procedural aspects more strongly than conceptual understanding. Although this approach may facilitate learning during the initial stages of instruction, the predominance of procedural representations may lead students to develop concept images that are not fully consistent with the formal definition of the F distribution. Therefore, achieving a better balance between procedural and conceptual representations should become an important consideration in the development of statistics textbooks and in statistics instruction at the university level.

4. CONCLUSION

This study demonstrates that the representation of the homogeneity of variance test in the analyzed educational statistics textbooks is predominantly procedural, particularly through the use of the F-test formula in which the larger variance is consistently placed in the numerator and the smaller variance in the denominator. Although this procedure is mathematically correct and facilitates statistical computation, most textbooks provide insufficient conceptual explanations of the F distribution, the rationale for using this variance ratio, and the possibility of obtaining F values less than one. Consequently, these representations may lead students to develop the misconceptions that the larger variance must always be placed in the numerator and that the F statistic can never be less than one. From the perspective of the **Concept Image–Concept Definition** framework, these misconceptions arise from an imbalance between procedural and conceptual representations in textbook presentations. Therefore, the development of educational statistics textbooks should place greater emphasis on the conceptual foundations underlying computational procedures in order to promote a more comprehensive understanding of statistical concepts and reduce the likelihood of misconceptions among students.

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