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Inferential Statistical Literacy of Mathematics Education Students with Field Independent and Field Dependent Cognitive Styles

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Abstract

Background/purpose. This study aims to examine the inferential statistical literacy of mathematics education students based on their cognitive styles—field-dependent (FD) and field-independent (FI). Inferential statistical literacy involves not only understanding statistical concepts such as hypothesis testing and parameter estimation but also applying them critically and appropriately in real-world contexts.

Materials/methods. A qualitative descriptive method within a case study design was employed. Two students, each representing FD and FI cognitive styles, were selected as subjects. Data were collected using the Group Embedded Figures Test (GEFT), statistical literacy problems, and structured interviews. The data were analyzed qualitatively and categorized according to indicators of inferential statistical literacy: formulating hypotheses, testing hypotheses, and making decisions.

Results. The findings revealed clear differences in reasoning patterns between the two cognitive styles. FI students demonstrated strong analytical thinking and provided logical justifications throughout the problem-solving process. In contrast, FD students relied more on procedural thinking and often failed to explain their reasoning clearly, showing limited conceptual understanding.

Conclusion. Students with a field-independent cognitive style demonstrated high levels of inferential statistical literacy, whereas those with a field-dependent style were at a moderate level. The difference in inferential statistical literacy between the two groups was quite substantial, which qualitatively indicates the influence of cognitive style on inferential statistical literacy. These findings underscore the need for instructional strategies tailored to cognitive style differences in order to support the development of inferential statistical literacy in mathematics education.

1. Introduction

Statistics is a key component of the mathematics curriculum. In its principles and standards for school mathematics, the National Council of Teachers of Mathematics (NCTM, 1989) identified "Data Analysis and Probability" as one of five core content standards, alongside Numbers and Operations, Algebra, Geometry, and Measurement. The significance of Statistics is also reflected in the 2013 Curriculum as one of the key areas of mathematics. At the elementary school level, the curriculum encompasses three main areas of study: numbers, geometry and measurement, and data processing. The mathematics curriculum at the junior high school level includes algebra, geometry, and measurement, as well as statistics and probability. At the higher education level, the curriculum encompasses algebra, geometry, statistics and probability, trigonometry, and calculus. Based on the mathematics curriculum and the NCTM standards, statistics is recognized as a fundamental domain, as it is introduced as early as elementary education. This aligns with Franklin et al. (2007), who asserted that statistics is a key component of the mathematics curriculum. Statistics are taught not only at the elementary and secondary levels but also at the tertiary level. The primary purpose of learning statistics is to develop statistical literacy. The growing importance of statistics in everyday life and the workplace underscores the need for greater emphasis on statistical literacy within the mathematics curriculum (Sharma, 2017). The importance of understanding statistical information has been emphasized by various organizations in the United States, including the American Library Association. Despite the growing demand for statistics education, it has historically been perceived by many students as a difficult and unenjoyable subject, and by many teachers as frustrating and challenging to teach. As enrollment in introductory statistics courses increases, educators face numerous challenges in supporting student success in learning statistics (Ben-Zvi & Garfield, 2004).

Statistical literacy has been recognized as essential knowledge for all citizens in today's information-driven society. According to Gal (2002), statistical literacy involves demonstrating a basic understanding of fundamental statistical concepts and procedures. Extensive research on statistical literacy has been conducted from 1980 to 2023, covering elementary schools, junior high schools, and universities. Strengthening statistical literacy in the mathematics curriculum is essential, given the critical role of statistics in both daily life and professional settings (Marchy & Juandi, 2023). Statistical literacy refers to an individual's ability to understand, interpret, and communicate data related to fundamental statistical concepts and procedures. It encompasses the capacity to apply statistical concepts to diverse problems, engage in statistical reasoning, and utilize statistical principles, procedures, and facts to describe statistical phenomena (Elfitra & Siregar, 2020; Shobikhah et al., 2025). Undergraduate students require statistical knowledge and skills to support their academic pursuits and everyday decision-making. Takaria (2015) emphasized that students' statistical literacy skills are crucial and must be enhanced for several reasons: (1) they enable students to comprehend statistical information effectively and support sound decision-making; (2) they assist students in writing theses, particularly in processing and analyzing research data; and (3) they equip students to respond to societal issues and activities involving statistical information. In addition to descriptive statistics, inferential statistics play a crucial role and are essential for students to master. A solid understanding of inferential statistics is vital. Interest in inferential statistics stems from three primary reasons. First, inferential statistics is highly relevant to the advancement of research across all empirical sciences, particularly in psychology and education (Belia, Fidler, Williams, & Cumming, 2005; Krauss & Wassner, 2002). Second, inferential statistics receives particular emphasis in statistics courses across nearly all scientific disciplines, where students learn hypothesis testing and confidence intervals as methods for evaluating scientific hypotheses (Aberson, Berger, Healy, & Romero, 2003). Finally, inferential concepts are prone to misunderstandings, and students frequently experience significant difficulties (Daniel, 1998; Kirk, 2001) because they must grasp and connect several abstract ideas, such as sampling distributions and significance levels (Elisa et al., 2009). Therefore, it is

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essential to obtain a comprehensive understanding of students' statistical literacy from a qualitative perspective, particularly regarding inferential statistics.

People often assume that statistics presented in the media are accurate, which can result in poor decision-making (Ben-Zvi & Garfield, 2004). A society with strong statistical literacy enables individuals to critically evaluate and effectively interpret the vast information available today (Rumsey, 2002). According to Kimura, as cited in Aoyama and Stephens (2003), a key component of statistical literacy is the ability to extract qualitative insights from quantitative data and/or to generate new information by integrating both qualitative and quantitative sources. The ability to extract qualitative information from quantitative data is evident in the study of Yotongyosa et al. (2015), which aimed to assess the level of statistical literacy among undergraduate students in Thailand. This is consistent with the findings of Lukman & Wahyudin (2019), who examined the level of statistical literacy and the factors influencing its development among Indonesian undergraduate students. The statistical literacy model employed in this study is based on Gal's framework, which comprises two main components: a knowledge component, consisting of five cognitive elements—literacy skills, statistical knowledge, mathematical knowledge, contextual knowledge, and critical questions—and a dispositional component, which includes two elements: critical attitude, and beliefs and attitudes. The survey involved 114 students from both mathematics and mathematics education study programs, regardless of whether they had taken basic statistics. The results indicated that students demonstrated a relatively good level of statistical literacy in all components, with particularly strong performance in the knowledge component, although the dispositional component remained relatively low. The average statistical literacy score of students who had studied basic statistics was higher than that of students who had not. Based on the studies conducted by Lukman & Wahidin and Yotongyosa et al., it can be concluded that their research primarily employed quantitative approaches, focusing on statistical literacy through the analysis of written test results. Consequently, these studies did not explore the subject's thought processes or cognitive understanding of basic statistical concepts, whether in descriptive or inferential statistics. In other words, there remains a lack of research that documents students' progress in developing statistical literacy (Watson & Callingham, 2004). In fact, understanding students' thought processes regarding basic statistical concepts—both descriptive and inferential—can serve as a valuable reference for lecturers or educators in optimizing teaching strategies, instructional methods, and semester learning plans. Such insights can support students in developing the knowledge, strategies, and perspectives necessary to enhance their statistical literacy.

Students' statistical literacy skills tend to vary due to several influencing factors, one of which is cognitive style. Therefore, this study examines students' statistical literacy skills in relation to field-dependent and field-independent cognitive styles. The cognitive style referred to in this study is limited to psychological aspects, specifically field-dependent (FI) and field-independent (FD) cognitive styles. Individual differences can be categorized into cognitive types commonly referred to as cognitive styles. Individuals with field-independent cognitive styles tend to be more analytical when approaching problems compared to those with field-dependent cognitive styles (Asmara and Afifah, 2019). Moreover, field-independent individuals have demonstrated superior performance in solving mathematical problems relative to their field-dependent counterparts (Roberge & Flexer, 1983; Testu, 1984; van Blerkom, 1988). Consistent with the research conducted by Amalia, Wildani, and Rifa'i (2020) on students' statistical literacy based on field-dependent and field-independent cognitive styles, this study aims to determine the statistical literacy profiles of ninth-grade students in relation to their cognitive styles. The research subjects comprised two students: one with a field-dependent cognitive style and one with a field-independent cognitive style. The findings indicated that the student with a field-dependent cognitive style had difficulty interpreting data from tables, selecting appropriate data for bar charts, and accurately presenting bar charts. Conversely, the

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student with a field-independent cognitive style demonstrated the ability to interpret presented data, select appropriate data for bar charts, and accurately construct bar charts. Based on these findings, it can be concluded that statistical literacy skills—specifically in data interpretation and presentation—differ between students with field-dependent and field-independent cognitive styles. Previous studies have predominantly focused on descriptive statistics rather than inferential statistics. Therefore, this study aims to examine the statistical literacy skills involved in solving inferential statistics problems among students exhibiting field-dependent and field-independent cognitive styles.

This article aims to describe the statistical literacy skills of students with field-dependent and field-independent cognitive styles in solving inferential statistics problems. It is hoped that the findings will provide insights into the statistical literacy of mathematics education students, thereby serving as a foundation for developing learning strategies, instructional methods, and curricula that enhance students' mastery of both descriptive and inferential statistical concepts, ultimately improving their overall statistical literacy.

Although previous studies have explored statistical literacy among mathematics education students as well as the general population, these studies have often focused more on descriptive statistics and employed large-scale quantitative approaches, without revealing how students cognitively understand inferential concepts. Moreover, although research has shown that students with a field-independent cognitive style tend to perform better than their field-dependent peers in statistical thinking tasks (Lailiyah, Muslimah, & Sutini, 2021), little is known about how these cognitive styles manifest within the process of inferential statistical literacy itself. Therefore, this study aims to fill that gap by qualitatively comparing two students with different cognitive styles in solving inferential statistics tasks.

2. Literature Review

The term inferential statistical literacy in the context of this study is developed as an extension of the concept of statistical literacy, which has been widely discussed in the statistics education literature. Gal (2002) defines statistical literacy as an individual's ability to understand, interpret, and critically evaluate statistical information in various everyday contexts, as well as to use such information to make reasoned decisions. This concept includes two main components: statistical knowledge and a critical disposition toward data and uncertainty.

According to Watson and Callingham (2004), statistical literacy develops hierarchically through six levels, ranging from idiosyncratic understanding to the highest level characterized by the ability to engage in critical mathematical thinking. At the intermediate to advanced levels, individuals demonstrate the ability to interpret data within context, consider uncertainty, and draw reasonable conclusions from statistical information—all of which are hallmarks of inferential thinking.

Makar and Rubin (2009) emphasize that inferential reasoning is at the core of mature statistical thinking. This reasoning involves not only the application of procedures such as hypothesis testing, but also the ability to formulate inferential questions, make decisions based on sample data, and assess the degree of accompanying uncertainty. Therefore, inferential statistical literacy requires a deep understanding of how conclusions are drawn from limited data in order to make generalizations about a population.

Franklin et al. (2005), in the GAISE Framework (Guidelines for Assessment and Instruction in Statistics Education), formulated four stages of the statistical problem-solving process: (1) formulating statistical questions, (2) collecting relevant data, (3) analyzing data, and (4) interpreting results to draw conclusions. The three indicators of inferential statistical literacy that are the focus of this study—formulating hypotheses, testing hypotheses, and drawing conclusions—are positioned in

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the analysis and interpretation phases. These stages require a deep understanding of context, statistical procedures, and logical inference.

Furthermore, Watson and Callingham (2004) developed a hierarchical model of statistical literacy consisting of six developmental levels: idiosyncratic, informal, inconsistent, consistent non-critical, consistent critical, and critical mathematical. The three indicators proposed in this study fall within the consistent critical level and above, where students are not only able to carry out statistical procedures but also connect them to the context and evaluate the validity of conclusions. This placement is further supported by the Rasch model-based study by L'Boy and Khan (2023), which categorizes statistical literacy skills into three hierarchical levels: (1) Tautological Concepts, (2) Non-Contextual Understanding, and (3) Critical Statistical Thinking and Reasoning. See Table 1.

Table 1. Alignment of Inferential Statistical Literacy Indicators with Theoretical Frameworks

Indicator of Inferential Statistical Literacy	Supporting Theoretical Framework	Cognitive Level
Formulating Hypotheses	GAISE levels 2 and 3 (Franklin et al., 2005); Rasch level 1 (L'Boy & Khan, 2023); Watson & Callingham (2004) level consistent critical	Early Inferential Reasoning
Conducting Hypothesis Test	GAISE level 3 (Franklin et al., 2005); Rasch level 2 (L'Boy & Khan, 2023); Watson & Callingham (2004) level critical mathematical	Procedural dan conceptual
Making Decision	GAISE level 4 (Franklin et al., 2005); Rasch level 3 (L'Boy & Khan, 2023); Watson & Callingham (2004) level critical mathematical	Critical and Reflective Thinking

3. Methodology

Research Design

This study employs a descriptive qualitative design with an intrinsic case study approach. The selection of subjects based on field-dependent and field-independent cognitive styles to solve inferential statistical problems aims to yield valuable insights within the academic context. Intrinsic case studies are particularly relevant when the case under investigation possesses unique characteristics that warrant in-depth exploration (Hadi et al., 2021). Moreover, case studies allow participants to articulate the meaning of their experiences related to statistical literacy, making this approach especially suitable for research that seeks detailed and comprehensive explanations (Creswell, 2014).

Participant

The subjects of the study were mathematics education students at Hasyim Asy'ari University who had taken statistics courses. The subjects of this study were female students with moderate mathematical abilities, as indicated by their GPA. A GEFT test was conducted to determine students with field-dependent and field-independent cognitive styles. The Group Embedded Figures Test (GEFT) is an instrument developed from EFT by Witkin et al. (1997) used to classify individuals according to their FD and FI cognitive styles. Among the 10 students, one student with a field-

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dependent cognitive style and one student with a field-independent cognitive style were selected. Based on GEFT results, both students demonstrated field-dependent and field-independent cognitive styles, respectively, and met the criteria for moderate mathematical ability.

Research Instruments

This study used two main instruments: a cognitive style test and statistical literacy problems. The cognitive style test aims to collect data specifically related to students' cognitive styles. The results of this assessment provided initial data for classifying the subjects. Students' cognitive styles were categorized based on the GEFT (Group Embedded Figure Test) scores. The criteria used were as follows: students who answered 10 to 18 questions correctly were classified as having an FI cognitive style, while those who answered fewer than 10 questions correctly were classified as having an FD cognitive style. The GEFT test was conducted offline following the technical instructions prepared by the researcher. In addition to categorizing cognitive styles, participants' statistical literacy skills were assessed through statistical literacy problems. This test was validated by three experts, namely three lecturers in mathematics education who teach statistics at universities in Surabaya and Ambon. The statistical literacy problem consisted of one question designed to assess participants' proficiency in statistical literacy. This question is presented in Figure 1. The instrument, in the form of statistical literacy problems, was used to collect data on statistical literacy and was complemented by in-depth interviews. The main aspects investigated in students' statistical literacy include their understanding of inferential statistics, specifically the material on testing the mean of two populations in paired samples. The single question in Figure 1 represents students' understanding of this topic.

A teacher suspects that the cooperative learning model is effective in teaching Integral material to 11th-grade students at a public high school (SMAN) in Jombang City, East Java Province. Learning is considered effective if it can increase student learning outcomes by more than 45 points. To test this hypothesis, the researcher selected one 11th-grade class consisting of 31 students as a representative sample. Before and after being taught Integral material using the cooperative learning model, the students were given tests and the following results were obtained in the table :

Students	*Pretest*	*Postest*
1	*20*	*70*
2	*25*	*85*
3	*15*	*65*
⋮	⋮	⋮
31	*30*	*70*

Can the teacher's hypothesis be accepted at a significance level of 0.05? What decision can be made based on the conclusion? (Assuming the population is normally distributed)

Figure 1. Inferential Statistical Literacy Problems

Data Analysis Techniques

The data analysis process follows a structured approach, involving classification, data reduction, data presentation, and data interpretation (Miles et al., 2013). See Figure 2.

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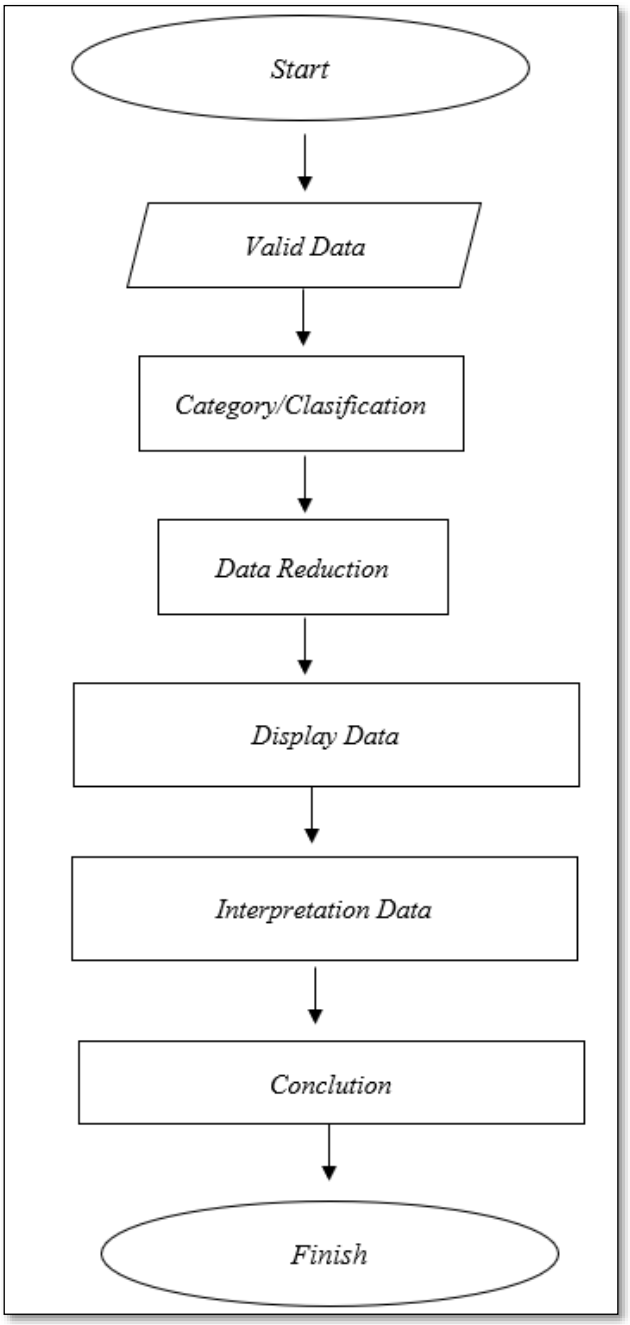

Figure 2. Flowchart of Data Analysis Method

Classification is based on statistical literacy indicators, and data collected from two statistical literacy tests are analyzed using data triangulation. Student responses are compared and processed through this triangulation technique. To ensure the validity of the data, triangulation is applied. Triangulation is a technique for verifying data validity by using sources other than the data itself for comparison or confirmation (Moleong, 2013). There are three types of triangulation: source triangulation, technique triangulation, and time triangulation (Sugiyono, 2010). This study employs time triangulation, which involves providing additional questions equivalent to the previous ones and conducting data interviews at different times and under varying conditions.

Data reduction is conducted by summarizing and focusing on the main information, selecting relevant points, and eliminating irrelevant data, with particular emphasis on statistical literacy indicators obtained from the interview results. The data are then presented in narrative or concise descriptions of students' statistical literacy, based on field-dependent and field-independent cognitive styles.

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Finally, data interpretation involves analyzing students' work, interviews, responses, and confirmations provided by students with field-independent and field-dependent cognitive styles. In the final stage, the researcher synthesizes the findings and draws conclusions. The statistical literacy indicators used to evaluate student performance in solving inferential statistical problems are presented in Table 2.

Table 2. Inferential Statistical Literacy Indicators

STAGES	Statistical Literacy Indicators
Formulating Hypothesis	1. Mentioning Population (RH1) 2. Mentioning Sample (RH2) 3. Mentioning Random Variables from the given problem (RH3) 4. Mentioning Population Parameters Symbolically (RH4) 5. Mentioning Hypothesis Verbally based on the given problem (RH5) 6. Mentioning Hypothesis Symbolically (RH6)
Testing Hypothesis	1. Formulating Ho (UH1) 2. Formulating H1 (UH2) 3. Determining $\propto$ (UH3) 4. Determining Ho Rejection Criteria (UH4) 5. Calculating the Required Statistical Values (UH5) 6. Making Valid Conclusions (UH6)
Making Decision	Making decisions based on conclusions from test results (BK1)

4. Results

Data collection began after identifying students who met the established research criteria. One student who demonstrated a field-independent cognitive style and one student who demonstrated a field-dependent cognitive style were selected to participate in the study. Subsequently, data related to statistical literacy were collected through task-based interviews with the selected students. The analysis was based on the established statistical literacy indicators, which were examined through three stages: (1) formulating hypotheses, (2) testing hypotheses, and (3) making decisions. To ensure the reliability and validity of the data on students' statistical literacy, the time triangulation method was employed. This involved initial data collection followed by subsequent data collection stages. When differences were identified between data sets, a reduction process was applied. Issues related to the material on testing the mean of two populations for paired samples, presented to students with field-dependent and field-independent cognitive styles, were analyzed using valid indicators of students' statistical literacy abilities. Furthermore, students with a field-independent cognitive style were coded as SI, and students with a field-dependent cognitive style were coded as SD.

Formulating Hypothesis

The subjects discussed the problem presented in Figure 1 by providing solutions and explanations for their reasoning in formulating hypotheses. Subject responses are detailed in the interview excerpts presented in Table 3.

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Table 3. SD Interview Quotes in Formulating Hypotheses

Code		Interview Description	Indicator Code (KI)
P1-2	:	Okay, after you read and study it carefully, try to mention the population in the problem above!	
SD1-2	:	Hmmm… The population in this problem is all grade XI students who use cooperative learning in the city of Jombang.	
P1-3	:	Why was that group selected as the study population?	
SD1-3	:	Because all grade XI SMAN students in Jombang city were studied, as instructed in the question (as shown in the sentence).	
P1-5	:	Earlier, we discussed the population; now, regarding the sample, what is the sample in this problem?	RH1 and RH2
SD1-5	:	The sample in this question is 31 grade XI students in Jombang city.	
P1-6	:	Can you explain why that group is considered the sample?	
SD1-6	:	Because the number of students who will be tested using the cooperative learning model is 31, as explained in the question (while pointing to it).	
P1-10	:	Now, regarding the random variables studied, what is the random variable in the problem presented earlier?	
SD1-10	:	(Pause for a moment, then try to answer) The random variable is the student's learning outcomes, which exceed 45 points.	
P1-11	:	Why is it considered a random variable?	RH3
SD1-11	:	Because it has been explained in the question.	
P1-12		Which one?	
SD1-12		This sentence, Ma'am (while pointing to the sentence in the question).	
P1-19	:	Okay, next, try to pay attention to the question again. What are the Population Parameters based on the given problem?	
SD1-19	:	There is μ Ma'am.	RH 4
P1-20	:	Why do you think that is the population parameter?	
SD1-20	:	Because the researchers use the average learning outcomes.	

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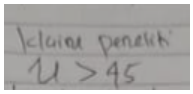
Code		Interview Description	Indicator Code (KI)
P1-26	:	Okay, now, how does the researcher's guess sound, verbally, based on the given problem?	
SD1-26	:	It is said that learning is effective if it increases student learning outcomes by more than 45 points.	RH5
P1-27	:	Why do you think that is the assumption?	
SD1-27	:	Because it is clearly explained in the problem, Ma'am (while pointing to the sentence in the question).	
P1-31	:	Now that you have responded verbally to the researcher's assumptions, how would you express a hypothesis symbolically?	
SD1-31	:	It is that the miu is greater than 45, Ma'am. *Subject Writing :* 	
P1-32	:	Why do you think that is the symbolic hypothesis?	RH6
SD1-32	:	Because in this problem the researcher suspects that the average student learning outcomes exceed 45 points, so I adjust the symbolic hypothesis to the verbal hypothesis.	
P1-33	:	Why do you think that particular symbol is used?	
SD1-33	:	Because in this problem, the researcher is concerned with the average student learning outcomes rather than standard deviations or other measures, Ma'am, the symbol used is μ	

The responses from Subject SD, as presented in Table 3, clearly demonstrate the students' statistical literacy, especially in formulating hypotheses. Based on the data analysis, the evaluation of SD's statistical literacy in solving inferential statistical problems at the hypothesis formulation stage is as follows: (1) correctly but incompletely identifying the population and sample, providing logical reasons, and effectively receiving information, yet unable to define the population and sample accurately and appropriately; (2) incorrectly and inappropriately mentioning random variables, offering insufficiently logical reasons, and failing to provide correct definitions and examples of random variables; (3) symbolically mentioning population parameters correctly but imprecisely, with reasons that are logical yet not critically sound, and and lacking accurate and proper definitions of population parameters; (4) verbally stating the research hypothesis correctly but incompletely, with fairly logical reasons; SD provides a correct yet incomplete and non-analytical definition of the research hypothesis; (5) writing the hypothesis symbolically in a generally correct but somewhat inaccurate manner, giving logical reasons for the symbolic representation, along with logical and analytical justification for the choice of symbols.

Next, the SI student subjects discussed the problems presented in Figure 1 by providing solutions and explanations for their reasoning in formulating hypotheses. The subject responses are detailed in the interview excerpts provided in Table 4.

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Table 4. SI Interview Quotes in Formulating Hypotheses

Code		Interview Description	Indicator Code (KI)
P1-3	:	Ma'am, after carefully reading and studying the problem, please identify the population mentioned in the problem above.	
SI1-3	:	That is all the students in class XI at SMAN Jombang City, East Java Province, Ma'am.	
P1-4	:	Why do you consider that to be the population?	
SI1-4	:	Because the population refers to the group from which the sample is drawn and used in the research. In the question, it is explained that the teacher suspects the cooperative learning model is effective for teaching Integral Material to Class XI students at SMAN in Jombang City, East Java Province.	RH1 and RH2
P1-7	:	Earlier, we discussed the population; now, regarding the sample, what is the sample in this problem?	
S I1-7	:	The sample consisted of 31 students from Class XI in Jombang City	
P1-8	:	Why was that group chosen as the sample?	
SI1-8	:	Because it has been explained in the question that the researcher chose one class XI, consisting of 31 students as a representative sample.	
P1-13	:	Okay, regarding the random variables studied, what is the random variable in the previous problem?	
SI1-13	:	The random variable is the cooperative learning model.	RH3
P1-14	:	Why is it considered a random variable?	
SI1-14	:	Because what will be studied is whether the cooperative learning model is effective or not.	
P1-20	:	Okay, next, try to pay attention again to the problem given, what are the Population Parameters based on the problem given?	
SI1-20	:	There is miu or average, the average is$\mu_2 - \mu_1$.	RH4
P1-23	:	Well, why do you think that's the population parameter?	
SI1-23	:	Because the value tested to show effectiveness is miu.	
P1-29	:	Okay, now, how does the researcher's guess sound, verbally, based on the given problem?	RH5

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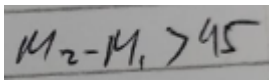
Code		Interview Description	Indicator Code (KI)
SI1-29	:	The assumption is that the learning model is effective for teaching integrals if it can improve student learning outcomes by more than 45 points.	
P1-30	:	Why do you think that is the assumption?	
SI1-30	:	Because it's already stated in the question, Ma'am (while pointing to the question).	
P1-31	:	Okay, can you show me a sentence that shows that this is the assumption?	
SI1-31	:	This one, Ma'am (While pointing to the researcher's alleged statement in the question).	
P1-37	:	Okay, if you have answered the researcher's assumptions verbally, now, in your opinion, how can a hypothesis be written symbolically?	
SI1-37	:	miu 2 minus miu 1 is bigger than 45 Ma'am.  TSI1-37	
P1-38	:	Why is that the symbolic hypothesis?	RH6
SI1-38	:	Because μ represents the population mean, specifically the average difference between the posttest and pretest scores. Additionally, the question states that learning is considered effective if the difference exceeds 45 points. Therefore, the symbolic hypothesis is μ2 − μ1 > 45	
P1-39	:	Okay, why do you think that particular symbol is used?	
SI1-39	:	Because the parameter being tested is the population mean, Ma'am, the symbol μ is used.	

The responses given by Subject SI, as presented in Table 4, clearly show the students' statistical literacy skills, especially in formulating hypotheses. Based on the data analysis, evaluation of SI's statistical literacy in solving inferential statistical problems at the hypothesis formulation stage is as follows: (1) correctly but incompletely identifying the population and sample, providing logical explanations, and effectively receiving information, yet unable to define the population and sample accurately; (2) incorrectly and imprecisely identifying random variables, offering insufficiently logical reasons, and failing to provide correct and precise definitions and examples of random variables; (3) Mentioning population parameters symbolically in the problem is correct and precise; the reasons provided are logical and critical, and SI can define population parameters correctly, though incompletely. (4) Verbally stating the research hypotheses is correct but incomplete; the explanations are fairly logical, and SI provides definitions of research hypotheses correctly but incompletely and with limited analytical depth. (5) Symbolically stating the hypothesis is accurate and appropriate; the reasons for the symbolic hypothesis are logically presented, and SI also offers logical and analytical justification for the symbol used.

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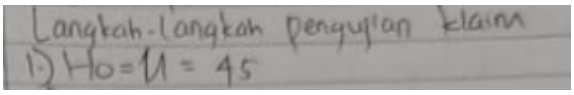
Testing Hypothesis

SD students' subjects tested the hypothesis related to the statistical literacy problem presented in Figure 1 correctly and systematically. However, certain aspects were inaccurate, and some of the justifications provided were illogical. This was attributed to the tendency of SD students to think procedurally during some stages. The subject's responses are detailed in the interview excerpts provided in Table 5.

Table 5. SD Interview Quotes in Formulating Hypotheses

Code		Interview description	Indicator Code (KI)
P1-21	:	How is the formulation H_0 on that issue?	
SD1-21	:	Ho is miu equals 45 *Subject Writing :*  TPSD1-21	UH1
P1-22	:	Why is that the formula H_0?	
SD1-22	:	Because Ho represents the hypothesis of no effect or no difference in the research.	
P1-24	:	What is the formulation H_1 of this problem?	
SD1-24	:	H1 shows that miu is greater than 45. *Subject Writing :*  TPSD1-24	UH2
P1-25	:	Why is that the formula H_1?	
SD1-25	:	Because H1 aims to see whether there is a difference before and after cooperative learning is given.	
P1-27	:	What is the level of significance of the problem?	
SD1-27	:	0.05.	
P1-28	:	What is the meaning of the level of significance in hypothesis testing?	UH3
SD1-28	:	The level of significance used by the researchers is 0.05, indicating an acceptable error rate and ensuring that the research maintains a relatively low probability of Type I error.	
P1-29	:	What are the rejection criteria for Ho in that problem?	UH4

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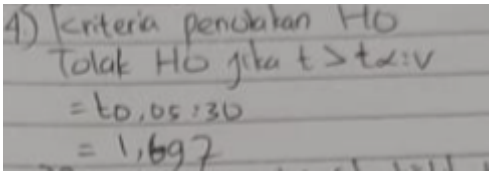
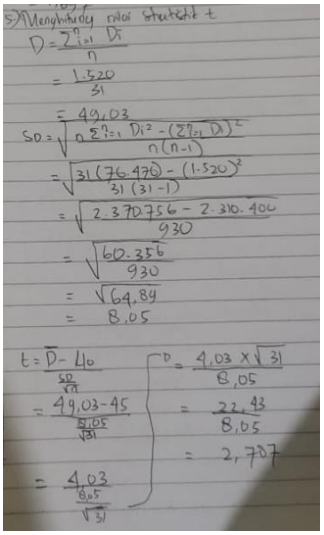
Code		Interview description	Indicator Code (KI)
SD1-29	:	The null hypothesis is rejected if the calculated t-value exceeds the critical t-value from the table. *Subject Writing :*  TPSD1-29	
P1-30	:	Why is that the rejection criterion for the null hypothesis (H_0)?	
SD1-30	:	Because… (while thinking) I forgot, Ma'am, I chose based on the examples that have been given.	
P1-31	:	In your opinion, what do the rejection criteria for the null hypothesis (H_0)indicate?	
SD1-31	:	When the calculated ttt-value is greater than the critical ttt-value from the table, the researcher's claim is accepted; thus, the alternative hypothesis (H1) is accepted, allowing a conclusion to be drawn.	
P1-32	:	What statistical formulas do you use to solve this problem?	
SD1-32	:	Formula for Di, D bar, standard deviation D, t count, and t table. *Subject Writing :*  TSD1-32	UH5
P1-33	:	Why do you consider this the right statistical formula to solve the problem?	

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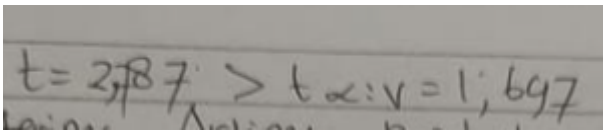
Code		Interview description	Indicator Code (KI)
SD1-33	:	Because there is only one sample, the formula for testing the mean of one population is used.	
P1- 34	:	What conclusions can you draw based on the calculations you have made?	
SD1-34	:	Thus, Ho is rejected, and the teacher's claim is accepted, indicating that cooperative learning is effective in teaching integral material and improving learning outcomes.	
P1-35	:	Why do you think that is the conclusion?	
SD1-35	:	Because in the previous calculation, the calculated t is greater than the table t. *Subject Writing :*  TSD1-35	UH6
P1-36	:	Does the significance level value (∝)influence the conclusions made? Why?	
SD1-36	:	It does not have an effect because the calculated statistical value holds greater significance.	

SD subjects are able to complete the statistical literacy problem hypothesis testing correctly; however, there are inaccuracies in formulating H_0 and H_1. Additionally, reasons provided for determining the rejection criteria of $H_0$and the selection of the statistical calculations used are also incorrect and imprecise. Based on data analysis, the data used to assess the statistical literacy ability of SD subjects in solving inferential statistical problems at the hypothesis testing stage are related to the activities carried out by SD subjects, namely: (1) *Formulating H_0less precisely, explaining reasons logically and analytically but incompletely, and not yet able to defineH_0 precisely and correctly;* (2) *Formulating H_1inaccurately, explaining illogical and non-analytical reasons, and not able to define H_1 accurately and correctly;* (3) *Correctly stating the values of α\alphaα, explaining reasons logically, and able to define levels of significance in hypothesis testing, but less precisely;* (4) *Can state the determination of rejection criteria for H_0correctly, but explains the reasons illogically and non-analytically in determining these criteria, and states the role of the rejection criteria for H_0 correctly but incompletely;* (5) *Calculates the required statistical values correctly, explains the reasons logically but incorrectly, inappropriately, and inconsistently;* (6) *Draw conclusions correctly and precisely, explains the reasons logically and analytically, but explains whether there is a significant influence on the conclusions incorrectly, with illogical reasons.*

Next, the SI student subjects discussed the problem presented in Figure 1 by providing solutions and explanations regarding the reasons for testing the hypothesis on the problem. The subjects' responses are detailed in the interview excerpts provided in Table 6.

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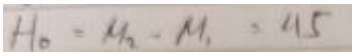
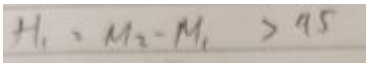
Table 6. SI Interview Excerpts in Testing Hypotheses

Code		Interview description	Indicator Code (KI)
P1- 42	:	Okay, sis, what's the next formula? H_0 in the problem that was solved earlier?	UH1
SI1- 42	:	The formula for Ho is miu 2 minus miu 1 equals 45. *Subject Writing :*  TSI1-42	
P1- 43	:	Why is that the formula for H_0?	
SI1- 43	:	Because $H_0$the formula must always use an equal sign, Ma'am, so the formula is like that.	
P1- 49	:	Okay, so what's the formula for H_1?	UH2
SI1- 49	:	H_1states that miu 2 minus miu 1 is greater than 45. *Subject Writing :*  TSI1-49	
P1- 50	:	Why is that the formula for H_1?	
SI1- 50	:	Because H_1 uses a sign according to the researcher's claim, the formula uses a greater-than sign.	
P1- 51	:	Does this mean that the sign on H_1 should match the sign in the researcher's claim?	
SI1- 51	:	Yes ma'am.	
P1- 58	:	Okay, fine. What is the level of significance of this problem?	
SI1- 58	:	The significance level is 0.05, Ma'am.	
P1- 59	:	How do you know?	
SI1- 59	:	It was mentioned in the question ma'am (While showing the sentence in question).	UH3
P1- 60	:	Okay. Now try to explain the meaning of the level of significance in hypothesis testing.	
SI1- 60	:	The level of significance represents the acceptable margin of error in the research, Ma'am.	

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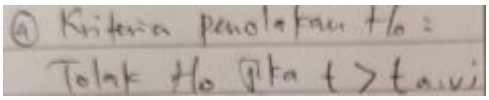
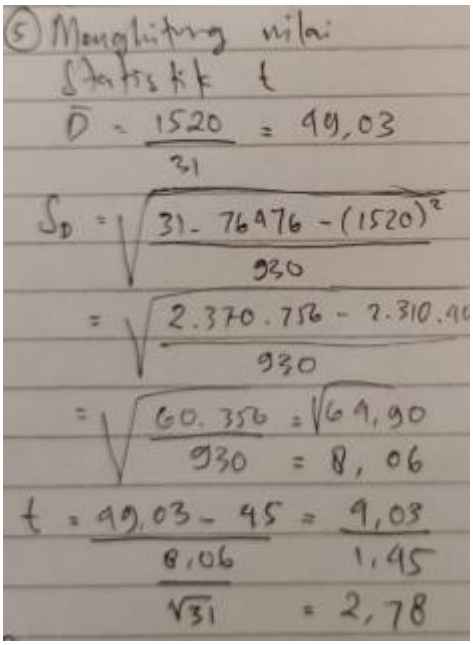
Code		Interview description	Indicator Code (KI)
P1- 65	:	Okay, now what are the rejection criteria for H_0 in the previous problem?	
SI1- 65	:	Reject H_0 if the calculated t is greater than the table t. *Subject Writing :*  TSI1-65	UH4
P1- 66	:	Why is that the rejection criterion for H_0?	
SI1- 66	:	… (while thinking), I chose it according to the example that you had given me before.	
P1- 73	:	Okay, then what are the statistical formulas used to solve this problem?	
SI1- 73	:	D bar, standard deviation D equals t count *Subject Writing :*  TSI1-73	UH5
P1-75	:	Well, why is the above-mentioned statistical formula the right one to use to solve this problem?	
SI1-75	:	Because the previous problem involved testing the mean difference between two populations using paired samples, Ma'am.	

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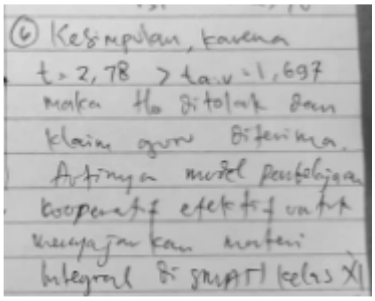
Code		Interview description	Indicator Code (KI)
P1- 81	:	What conclusions can be drawn based on the calculations you have made?	
SI1- 81	:	This is an effective cooperative learning model to teach integral material.	
P1- 83	:	Why do you think that is the conclusion	
SI1- 83	:	Because based on the criteria above, the calculated t is greater than the table t, ma'am. *Subject Writing :*  TSI1-83	UH6
P1- 87	:	OK, I guess. Is the significant level $(\propto)$affecting the conclusions made? Why?	
SI1- 87	:	Yes, ma'am, it does affect. It affects the t-table value, so if the t-table changes, it can affect the conclusion.	

The responses given by Subject SI, as presented in Table 6, show the students' statistical literacy abilities in testing hypotheses. Based on data analysis, the evaluation of Subject SI in solving inferential statistical problems at the hypothesis testing stage is based on activities including: (1) correctly formulating H_0, providing logical and analytical explanations, but lacking precision and accuracy in defining H_0; (2) formulate H_1correctly, offering logical and analytical reasoning, yet unable to define H_1 accurately and correctly. (3) Can state the significance level α correctly, provide logical explanations, and define the level of significance in hypothesis testing, albeit with less precision; (4) can correctly state the rejection criteria for H_0, but explanations are illogical and lack analytical depth; the role of the rejection criteria is stated correctly but incompletely; (5) can accurately calculate the required statistical values and provide logical, correct, and precise explanations; and (6) can draw conclusions correctly and precisely, with logical and analytical explanations, and clearly state whether the conclusion indicates a significant effect, supported by logical and analytical reasoning.

Make Decision

Subject SD provides logical and precise conclusions based on the decision-making process, supported by well-reasoned explanations. This is illustrated in the interview excerpts presented in Table 7 below.

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Table 7. SD Interview Excerpts in Decision Making

Code		Interview description	Indicator Code (KI)
P1-37	:	What conclusions can be drawn after analyzing the results of the given problem?	
SD1-37	:	Teachers should use cooperative learning models when teaching integral material.	
P1-38	:	What is the rationale behind that decision?	
SD1-38	:	Because, based on the previous conclusion, the learning model is effective.	
P1-40	:	Are there any other decisions you could have made besides those? If so, explain some of the decisions you could have made besides those already mentioned.	BK1
PSD1-40	:	No, Ma'am.	
P1-41	:	Why?	
SD1-41	:	Because this decision aligns with the teacher's hypothesis, it applies specifically to integral material. While it may also be effective for other topics, further testing is required to confirm this.	

Based on the data analysis, the data used to assess the statistical literacy skills of SD subjects in solving inferential statistical problems at the decision-making stage relate to the subject's activities, namely: making appropriate decisions and providing logical and analytical reasons, particularly regarding the impossibility of making alternative decisions without prior testing on other materials.

Similarly, the SI subjects made appropriate decisions based on the conclusions drawn after solving the statistical literacy problems. In addition, logical reasons were provided to support the decision made. The subject's responses are detailed in the interview excerpts presented in Table 8.

Table 8. Interview excerpts from SI in Decision Making

Code		Interview description	Indicator Code (KI)
P1-92	:	What decisions can be made after knowing the results of the conclusions related to the given problem?	
SI1-92	:	The decision was to use a cooperative learning model to teach integral material in class XI.	
P1-93	:	Why was that decision made?	
SI1-93	:	Because based on the previous conclusion, it is effective in applying the cooperative learning model to integral material.	BK1
P1-94	:	Well, is there any other decision that can be taken besides that?	
SI1-94	:	No, Ma'am.	
P1-95	:	Why?	
SI1-95	:	The decision was based on the conclusion drawn from the analysis. Therefore, the decision aligns with the conclusion, as it is inappropriate to make a decision that contradicts the findings.	

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Based on the data analysis, the data used to assess the statistical literacy ability of SI subjects in solving inferential statistical problems at the decision-making stage relate to the activities carried out by SI subjects. Specifically, SI makes decisions correctly and precisely, providing logical and analytical reasons regarding the impossibility of making alternative decisions. This is because decisions must be based on the results of the conclusions, and it is not permissible to make decisions without referring to these conclusions.

5. Discussion

The findings of this study provide valuable insights into the relationship between statistical literacy and cognitive styles, specifically field-dependent (SD) and field-independent (SI), as reflected in students' responses to statistical literacy problems. These problems focus particularly on testing the mean of two populations for paired samples and assess indicators such as formulating hypotheses, testing hypotheses, and making decisions based on conclusions. Students with a field-dependent (SD) cognitive style demonstrate the ability to formulate hypotheses, test them, and make decisions, although their responses occasionally contain errors, such as inaccuracies in formulating the hypothesis H_0 and H_1. Furthermore, field-dependent students sometimes fail to provide logical reasons for their answers due to limited conceptual understanding and a tendency on procedural thinking without grasping the underlying reasons. For example, SD subjects give illogical explanations for selecting the null hypothesis rejection criteria and the statistical formulas used. In contrast, Field-independent (SI) subjects demonstrate the ability to formulate hypotheses, test them, and make decisions correctly, with nearly all responses accompanied by logical and well-reasoned explanations. However, there is a point at which SI subject exhibit similar difficulties as SD subjects; specifically, when explaining the reasons for selecting the H_0 rejection criteria, both subjects give identical and illogical arguments. At this stage, both subjects tend to rely on procedural thinking. A schematic representation of the statistical literacy ability of students with field-dependent and field-independent cognitive styles is illustrated in Figure 3 below.

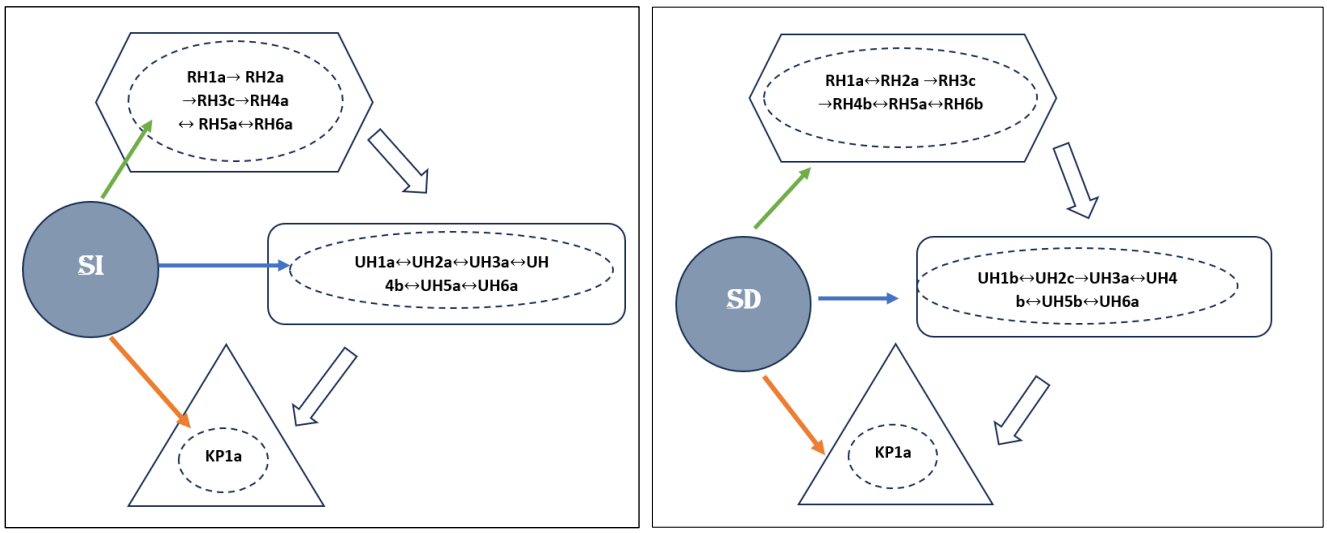

Figure 3. Schematic Representation of the Inferential Statistical Literacy of Students with Field-Dependent (SD) and Field-Independent (SI)

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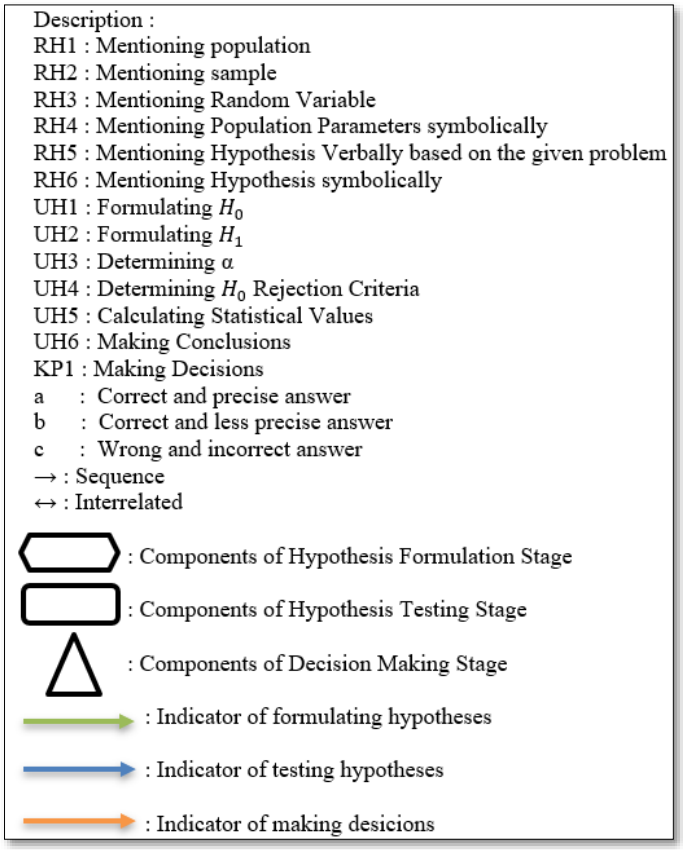

Figure 4. Detailed Description of the Schematic Representation of Students' Inferential Statistical Literacy (SD and SI)

The findings of this study provide valuable insights into the relationship between statistical literacy and cognitive styles, specifically field-dependent (FD) and field-independent (FI), as reflected in students' responses to inferential statistical problems. These problems focused on testing the mean of two populations for paired samples and evaluated key indicators such as formulating hypotheses, testing hypotheses, and making decisions based on statistical conclusions.

Students with a field-dependent cognitive style (FD) demonstrated the ability to complete all stages of statistical problem-solving. However, their answers often included conceptual inaccuracies, such as errors in stating null and alternative hypotheses, misinterpretation of rejection criteria, and a tendency to rely on procedural responses without logical justification. This suggests a surface-level understanding, which aligns with previous findings indicating that field-dependent learners frequently struggle with conceptual reasoning and are more influenced by contextual or surface features of problems (Amalia, Wildani, & Rifa'i, 2020; Afifah & Nafian, 2018).

Field-independent students (FI), on the other hand, demonstrated a deeper conceptual grasp of statistical procedures. Their responses were more accurate, analytically grounded, and logically justified. These students formulated hypotheses clearly, selected appropriate testing criteria, and explained their decisions using mathematical reasoning. Nevertheless, both FD and FI students exhibited similar difficulties in specific areas, such as justifying the rejection region criteria, indicating that even field-independent learners might revert to procedural thinking in complex situations—supporting Rahman, Juniati, and Manuharawati's (2022) findings that analytical strengths do not always translate into complete conceptual mastery.

The patterns observed reinforce existing literature on cognitive styles and mathematical reasoning. Research by Sutama et al. (2021) and Afifah & Nafian (2018) has consistently shown that field-independent learners tend to perform better in tasks requiring logical abstraction, symbol

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manipulation, and problem-solving flexibility. Field-dependent students, however, may perform adequately on procedural tasks but often lack depth in reasoning, especially when abstract thinking is required (Rahman et al., 2022).

Moreover, the observed strengths and limitations of each cognitive style align with the dual process theory in mathematical cognition, which posits that learners may oscillate between intuitive/procedural (System 1) and analytical/conceptual (System 2) processing (Evans, 2008; Kahneman, 2011). This study shows how both cognitive styles can engage in both systems but with differing levels of efficiency and consistency.

This study makes a unique contribution by offering a schematic differentiation of inferential statistical literacy based on cognitive style, which has been underexplored in previous research. Most prior studies focused on descriptive statistics or general problem-solving (Gal, 2002; Watson & Callingham, 2003), whereas this study specifically addresses inferential statistical reasoning, providing insight into how students cognitively approach hypothesis testing tasks.

The findings have practical implications for instructional design in statistics education. Tailored strategies can be developed to support both cognitive styles: for FD learners, this could involve scaffolding conceptual understanding with visual aids and context-based examples; for FI learners, providing complex, abstract challenges may enhance deeper learning. Furthermore, adaptive learning technologies could be employed to detect cognitive styles and adjust instruction accordingly (delMas et al., 2007; Chance et al., 2007).

6. Conclusion

This study shows that both field-dependent students and field-independent students have an understanding of formulating hypotheses, testing hypotheses, and making decisions related to these concepts. The responses from both groups were relatively accurate. Notably, during the interview, students were able to provide accurate and relevant supporting information, reflecting their capacity to engage with statistical literacy tasks more clearly and deeply during reflective dialogue. However, despite their general understanding, students showed conceptual and procedural errors in formulating and testing hypotheses. Moreover, during the interview, field-dependent students demonstrated more conceptual errors and lack of understanding of the relationship between concepts across several indicators. In contrast, field-independent students showed a better grasp of each concept underlying the reasons they presented when solving statistical literacy problems. This study indicates that students with a field-independent cognitive style tend to exhibit superior statistical literacy skills compared to field-dependent students.

7. Suggestion

Based on the findings and limitations of this study, future research is suggested to explore a broader range of inferential statistical problems and learning materials. Expanding the scope beyond paired sample mean tests will allow for a more comprehensive understanding of students' inferential statistical literacy. Additionally, future studies should involve a wider variety of cognitive styles, not limited to just field-dependent and field-independent, to examine how different cognitive characteristics influence students' learning processes and statistical reasoning. It is also recommended that future researchers use the insights gained from this study—particularly regarding the characteristics of proficient students—to develop more tailored instructional strategies and adaptive learning media. This can improve the effectiveness and efficiency of teaching, especially in diverse learning environments. Furthermore, applying similar research frameworks in different educational or cultural contexts could help validate the findings and reveal new insights into the development of inferencial statistical literacy among students.

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Declarations

Author Contributions. Conceptualization, I.R, I.K.B, and S.K..; methodology, I.R. and I.K.B.; formal analysis, I.R..; writing—original draft preparation, I.R.; writing—review and editing, I.R., I.K.B, and S.K; supervision, I.R., I.K.B, and S.K. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest. the authors declare no conflict of interest.

Data Availability Statement. The data used in this research is confidential and thus cannot be shared with third parties.

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