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Innovation in Inferential Statistics Learning: Predict, Observe, and Explain (POE)-Based Teaching Materials to Optimizing Adaptive Reasoning

Ria Deswita & Febria Ningsih
Institut Agama Islam Negeri Kerinci, Jambi, Indonesia
ria_deswita@ymail.com

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ABSTRACT

Inferential statistics is a cornerstone of higher education mathematics that equips students with essential skills for evidence-based decision-making, yet many undergraduates continue to face persistent difficulties in applying adaptive reasoning, particularly in hypothesis testing, regression analysis, and data interpretation. Conventional lecture-based and textbook-driven approaches tend to focus on computational procedures, leaving a crucial gap in cultivating reasoning and reflective thinking. Addressing this challenge, the present study developed Predict-Observe-Explain (POE)-based teaching materials explicitly designed to optimize adaptive reasoning in inferential statistics learning. Using a developmental research design guided by the Hannafin and Peck model, the study progressed through needs assessment, design, development, implementation, and continuous evaluation. Validity was established through expert reviews of content accuracy, pedagogical coherence, and presentation quality, while practicality was assessed via small- and large-group trials with undergraduate mathematics education students at IAIN Kerinci. Findings demonstrated high validity (90.75%) and acceptable practicality (77.6%), affirming the feasibility of integrating POE-based materials into undergraduate statistics instruction. By embedding prediction, observation, and explanation tasks into statistical problem-solving, the materials promoted students' logical reasoning and improved their ability to justify conclusions. This study extends the POE approach beyond its common use in science education to abstract mathematical contexts, providing an empirically validated instructional innovation that fosters higher-order reasoning. The findings contribute to enhancing curriculum design in mathematics education and support global priorities for advancing critical thinking, problem-solving, and data literacy as central competencies for twenty-first century learning.

1. Introduction

In today's data-driven world, the ability to make valid statistical inferences is indispensable for academic, professional, and civic decision-making. Inferential statistics enables students and researchers to generalize findings from samples to populations and to critically evaluate evidence in fields such as education, health, social sciences, and economics (Kim et al., 2019; Sandnes & Eika, 2018; Subramanian et al., 2019). It involves techniques for drawing conclusions about populations from sample data, including hypothesis testing, correlation, and regression analysis (Vetten et al., 2018). Therefore, undergraduate students need to master inferential statistics. However, many still encounter challenges, particularly in formulating and testing hypotheses, understanding statistical problems, and conducting correlation and regression analyses (Case & Jacobbe, 2018; Feronika et al., 2023; Yahya et al., 2024; Yuniarti, 2022). These difficulties arise because inferential statistics combines mathematical theory with real-world applications and requires not only computational skills but also higher-order reasoning and critical thinking (France & Krievina, 2022; Vetten et al., 2018).

A crucial skill for learning inferential statistics is adaptive reasoning, which refers to the ability to apply logical thinking, reflect on information, and provide explanations and justifications for conclusions (Jatisunda et al., 2024; Kilpatrick et al., 2001; Lestari et al., 2022). Adaptive reasoning supports other essential skills such as conceptual understanding and problem-solving (Ansari et al., 2020; Segerby & Chronaki, 2018) and plays a key role in addressing complex problems in inferential statistics (Makar & Rubin, 2022). Therefore, optimizing adaptive reasoning should be a primary goal in designing teaching materials for this subject. Nevertheless, many undergraduate students still struggle to apply this skill effectively (Haryadi & Oktaviana, 2021;

Lestari et al., 2022; Wasiran & Andinasari, 2019; Yenni & Kurniasi, 2018). Observations in one university in Jambi revealed that students frequently had difficulties in analyzing data and drawing conclusions, particularly in hypothesis testing, regression, and correlation analysis.

Traditional teaching methods, which often rely on lectures and textbook exercises, are insufficient to build strong reasoning and critical-thinking skills (Aouaf et al., 2023; Davies, 2011; Indrašienė et al., 2021). Many students tend to focus on memorizing formulas rather than applying them to solve problems (Lestari et al., 2022), which limits their ability to apply statistical concepts in real-world contexts. Addressing these challenges requires innovative approaches and well-designed learning materials that actively engage students in reasoning and problem-solving.

One promising approach is Predict, Observe, and Explain (POE), which consists of three interconnected steps: prediction, which involves formulating initial assumptions about a problem; observation, which requires collecting data or evidence; and explanation, which entails justifying and interpreting the results obtained (White & Gunstone, 2014). This approach encourages students to reflect on their thinking, compare predictions with observed results, and refine their understanding using empirical evidence (Adawiyah et al., 2023; Aulia & Yuliani, 2023; Fitriani et al., 2020). It has demonstrated potential in enhancing adaptive reasoning by prompting students to analyze their thought processes more deeply (Çalış & Özkan, 2022; Permatasari et al., 2023).

In inferential statistics learning, the POE approach encourages students to use logical reasoning when making predictions, to reflect on discrepancies during observation, and to justify conclusions during the explanation phase (Noor et al., 2023; Arslan & Emre, 2020; Arif & Sahara, 2022). Previous research has reported that the POE approach can improve critical thinking, conceptual understanding, learning outcomes, and the ability to address misconceptions (Amahoru et al., 2023; Arslan & Emre, 2020; Fitrianingsih et al., 2021; Kharis et al., 2024; Muhibbuddin et al., 2019; Muna, 2017; Murtihapsari et al., 2022). However, its specific role in optimizing adaptive reasoning among university students remains underexplored. The effective use of POE also requires well-structured teaching materials that guide students through each stage of prediction, observation, and explanation (Rini et al., 2019; Cahyadi, 2019; Husna & Pranoto, 2024).

Developing such materials demands attention to both statistical concepts and students' cognitive processes. The materials should present real-world problems that allow students to predict outcomes, observe phenomena, and explain their findings (Ulfa et al., 2020; Kumlu & Şahin, 2022). They should also provide opportunities for students to reflect collaboratively with peers and receive feedback from lecturers. Several studies have shown that POE-based worksheets, instructional packages, and handouts can improve critical thinking skills, conceptual understanding, and learning outcomes (Arif & Sahara, 2022; Noor et al., 2023; Purdhiyah et al., 2023). However, few have focused specifically on strengthening adaptive reasoning.

The novelty of this study lies in integrating the POE approach into inferential statistics teaching materials that specifically aim to enhance adaptive reasoning, a fundamental yet underexplored mathematical competency. Most prior research has applied POE to science topics at the secondary school level. This study extends its application to the abstract domain of university-level mathematics, focusing on inferential statistics. Guided by the Hannafin and Peck (1988) development model, the study followed systematic stages including needs assessment, design, development, implementation, and evaluation to ensure conceptual validity, practicality, and usability.

By embedding prediction, observation, and explanation tasks into statistical problem-solving activities, the materials aimed to connect students' prior knowledge with new concepts, strengthen their logical reasoning, and improve their adaptive reasoning skills. This study contributes to curriculum innovation and evidence-based teaching practice by extending the POE approach to a higher-education mathematics context. It also supports broader educational goals, including the development of critical thinking, problem-solving, and data literacy that are essential for learners in the twenty-first century. The findings highlight the potential of well-structured POE-based instructional materials to improve the quality of statistics education and provide a foundation for future research on their long-term impact on students' reasoning skills in diverse academic settings.

2. Literature Review

2.1 Adaptive Reasoning in Mathematics Education

Adaptive reasoning refers to the ability to formulate and apply logical reasoning strategies to solve problems in various contexts. This ability is important for someone to have, especially in mathematics education, because the ability to reason critically and adaptively is used to solve complex problems (Jatisunda et al., 2024; Susilawati et al., 202). Adaptive reasoning plays an important role in the academic success of undergraduate students, especially in mathematics. Thus, the importance of adaptive reasoning in mathematics education means that adaptive reasoning is one of the main abilities that must be developed in undergraduate students (Jatisunda et al., 2024; Putra & Sari, 2016).

Adaptive reasoning can be developed through the application of creative and reform-oriented learning approaches, this shows that the learning environment must be responsive to the needs and capacities of undergraduate students to develop adaptive reasoning (Darwani et al., 2020; Jatisunda et al., 2024; Putra & Sari, 2016). Previous study shows that the increase in adaptive reasoning in students whose learning is implemented using reform-based learning models such as creative problem-solving models is higher than that of traditional learning models (Ansari et al., 2020; Susilawati et al., 2021).

Recent studies show that students with strong adaptive reasoning can develop flexible strategies and think at a higher level (Ansari et al., 2020; Jatisunda et al., 2024). Still, adaptive reasoning is often underdeveloped in university classrooms, where procedural skills are typically the primary focus rather than reflective or reasoning activities (Susilawati et al., 2021). Because of this, there is a need for teaching methods that help students develop reasoning skills while learning the content.

2.2 Challenges in Inferential Statistics Learning

Inferential statistics is very important in educational and professional fields, especially when analyzing data in fields such as medicine, psychology, and education (Kim et al., 2019; Sandnes & Eika, 2018; Subramanian et al., 2019). In the field of education, inferential statistics is one of the materials that must be studied at the college level. Inferential statistics encompasses statistical methods such as parametric and nonparametric tests, confidence intervals, hypothesis testing, correlation analysis, and regression analysis (Muhammad & Akhsani, 2021). Lecturers must design learning and teaching materials that aim to improve the understanding and reasoning of undergraduate students in inferential statistics courses. Designing inferential statistics teaching materials must pay attention to the knowledge and obstacles that occur in learning. Studies show that obstacles that occur such as conceptual errors can hinder effective teaching (France & Krievina, 2022). In addition, what often happens to undergraduate students in learning statistics is difficulty in applying reasoning to solve problems (Lestari et al., 2022; Sari, 2017). Integrating instructional strategies that address these methods should also promote critical thinking, analytical reasoning, and the practical application of statistical concepts in real-world contexts.

Research indicates that students often misunderstand hypothesis testing, correlation, and regression analysis (France & Krievina, 2022; Lestari et al., 2022). While many can perform statistical calculations, they frequently struggle to justify or interpret results effectively (Sari, 2017). These findings suggest that procedural skills alone are not enough; students require structured opportunities to develop reasoning and achieve deeper understanding. There is a clear need for instructional designs that connect computation with reasoning in statistics education.

2.3 Predict, Observe, and Explain (POE) Approach

The Predict-Observe-Explain (POE) learning approach is designed to enhance students' comprehension and engagement with scientific concepts. The POE approach consists of three phases: predicting the outcome of an experiment or analysis, making observations, and then explaining the reasoning behind the observed resultsn (White & Gunstone, 2014). This method actively engages undergraduate students, enabling them to address misconceptions and deepen their conceptual understanding (Sıriş & Çoştu, 2024).

Previous studies have shown that the POE approach can improve mathematical ability (Amahoru et al., 2023; Arslan & Emre, 2020; Fitrianingsih et al., 2021; Kharis et al., 2024; Muhibbuddin et al., 2019; Muna, 2017; Murtihapsari et al., 2022). In addition, the POE approach is also able to improve understanding and overcome misconceptions (Zakiyah et al., 2019). This is important because misconceptions are often an obstacle in learning

Activities in the POE approach encourage undergraduate students to make predictions that can help them improve their metacognitive skills and reasoning abilities (Kumlu & Şahin, 2022). In addition, the prediction phase helps students improve understanding by thinking logically in making assumptions before observations (Alfiyanti et al., 2020). Activities in the observation and explanation phases can encourage students to think critically and reason skill (Fitrianingsih et al., 2021; Murtihapsari et al., 2022). Prediction, observation and explanation activities in the approach are carried out by means of discussion.

Discussion activities in the POE approach can encourage collaboration and communication among undergraduate students, so that they can bring together different points of view so as to improve their understanding (Şeşen & Mutlu, 2016). In addition, discussion activities in the POE approach not only improve the quality of learning but also support the development of critical thinking skills (Alfiyanti et al., 2020). Nevertheless, the use of this approach in abstract, conceptually demanding domains such as university level inferential statistics remains limited, leaving a clear and important research gap. Responding to this gap, the present study positions itself at this intersection by adapting and validating POE based teaching materials that are explicitly designed to optimize students' adaptive reasoning in higher education mathematics, particularly in inferential statistics.

3. Method

This study was initiated based on the observation that many undergraduate students face persistent challenges in learning inferential statistics, particularly in hypothesis testing, regression analysis, and data interpretation. These challenges are largely attributed to the abstract nature of statistical concepts and the lack of suitable instructional materials that bridge theory and practice. It was assumed that teaching materials based on the Predict, Observe, and Explain (POE) approach could offer more meaningful opportunities for students to strengthen adaptive reasoning and deepen conceptual understanding.

3.1 Research Design

This study employed a developmental research design aimed at producing a learning product in the form of POE-based teaching materials for inferential statistics. The development followed the Hannafin and Peck (1988) model, which is widely recognized for its systematic and iterative structure. The model consists of three main stages: (1) needs assessment, (2) design, and (3) development and implementation. Each stage was followed by formative evaluation and revision to ensure both conceptual validity and practical usability of the final product.

3.2 Participants and Context

The trial was conducted at the Department of Mathematics Education, Faculty of Education and Teacher Training, IAIN Kerinci. The participants were undergraduate students enrolled in the Educational Statistics course, representing the intended users of the developed materials. The implementation process involved two groups of participants: a small group of five students for the initial trial and a large group of fifteen students for the subsequent trial. This sequential approach allowed the researchers to identify and address potential usability issues before scaling up.

3.3 Development Process

1) Needs Assessment

The first stage focused on identifying challenges and defining the requirements for the instructional product. Several steps were undertaken, including problem identification, goal setting, learner analysis, reviewing existing instructional resources, and preparing a development plan. Field observations revealed that students struggled with adaptive reasoning and faced didactic obstacles related to existing textbooks. The textbooks were often abstract, and the examples provided were difficult to follow, indicating the need for more coherent, systematic, and contextually relevant materials that could encourage students to explore concepts independently. The findings highlighted the necessity of developing POE-based materials tailored to inferential statistics.

2) Design

The second stage involved translating the identified needs into a structured instructional product. The teaching materials were organized into three main components: the introduction (cover page, foreword, and table of contents), the content section (key concepts, detailed explanations, and sample problems), and the closing section (practice questions to reinforce understanding). The selection and organization of the content were guided by learning objectives and performance indicators aligned with inferential statistics concepts.

During this phase, instruments for evaluation were also designed. The feasibility of the materials was assessed using a validation sheet that examined two major aspects: (1) content and material quality and (2) presentation and visual design. Validation instruments were developed according to specific indicators for each criterion and were evaluated by two expert validators for each aspect. Additionally, a student response questionnaire was created to assess the practicality of the materials in real classroom settings. The questionnaire comprised 18 items covering four dimensions: usefulness, ease of use, attractiveness, and efficiency.

3) Development and Implementation

In the third stage, the teaching materials were produced and validated by two experts, one specializing in content and material quality and the other in presentation and display. Feedback from validators served as the basis for improving the materials. Suggested revisions included restructuring the presentation of the "one-way testing" section into clearer sub-points and revising example problems to explicitly align with the stages of POE.

Following these revisions, the materials underwent a two-step implementation process. The small-group trial involved five students who reviewed and used the materials, then provided feedback via questionnaires. After confirming their practicality, the materials were tested in a large-group trial with fifteen students over five instructional sessions to evaluate usability in a broader classroom context.

3.4 Data Collection

Data were gathered using three complementary techniques:

1) *Validation sheets* were used to collect expert assessments on the quality of content, structure, and presentation of the developed materials.
2) *Student questionnaires* were administered to capture user perceptions of practicality during both small and large group trials.
3) *Observations* were carried out throughout the teaching sessions to document student engagement and challenges encountered when using the POE-based materials.

Before use, all instruments were pre-tested and validated to ensure their reliability and appropriateness for the study.

3.5 Data Analysis

The data were analyzed using both qualitative and quantitative approaches. The qualitative analysis focused on feedback from expert validators and open-ended responses from students and was used to identify necessary revisions to improve the product. The quantitative analysis included calculating validation scores provided by experts to determine the overall validity of the materials, as well as analyzing questionnaire responses from students to assess the practicality of the developed product.

The validity of the materials was determined by calculating the percentage scores across the assessed aspects. A product was considered valid if it achieved a score exceeding the threshold of acceptability established by expert judgment. Similarly, the practicality of the materials was evaluated through percentage ratings of student responses, with higher scores indicating a more user-friendly and effective learning tool.

3.6 Ethical Considerations

All participants were informed about the purpose of the study and voluntarily provided their consent to participate in the trials. The research followed ethical guidelines for educational research, ensuring confidentiality and the responsible use of collected data.

4. Result

This study aims to develop teaching materials for educational statistics courses. The study was conducted at the Department of Mathematics Education, Faculty of Education and Teacher Training, IAIN Kerinci. This study has produced teaching materials for learning inferential statistics based on the POE, which have been validated by experts, tested on undergraduate students, and revised making them suitable for use. The development process involves three stages: the needs assessment, design, and development and implementation.

4.1 Needs Assessment

Needs assessment is the initial stage that must be carried out because at this stage, the problems found in the educational statistics lecture process are studied and then a way to solve the problems is formulated. At this stage, observations are conducted to gather information about the problems that arise in the field. Based on the observation result, it was found that undergraduate students' adaptive reasoning was low and there were didactic obstacles related to teaching materials. Most undergraduate struggle to comprehend the material in the textbook for their educational statistics course. Additionally, the example questions presented and the language used in the textbook are also quite challenging to understand. Based on this information, it can be concluded that undergraduate students need teaching materials that present material in a coherent and systematic manner so that they can learn and find the concept of the material themselves. The teaching materials that are in accordance with this are teaching materials based on POE.

4.2 Design of the Teaching Materials

In the design stage, several steps are taken, namely collecting materials to be developed into teaching materials, making products in the form of teaching materials according to the stated objectives, and determining testing techniques and strategies. Before designing teaching materials, the first step is to collect relevant materials and books that will be used in the compilation. After the materials are collected, the next stage is to design the teaching materials. Teaching materials consist of three parts, namely introduction, content, and closing. The introduction includes the cover, foreword, and table of contents. The content section includes a description of the material, starting from a general description of the material such as the definition and continuing with detailed sections such as concepts and sample questions. The closing section includes practice questions that can expand undergraduate students' knowledge. The material in the teaching materials is compiled from various references based on indicators and learning objectives.

The instrument used to assess the feasibility of teaching materials is in the form of a validation sheet covering material and content aspects as well as appearance and presentation aspects. The validation sheet is compiled based on the indicators for each assessed aspect. The assessment of the instrument in terms of feasibility is validated by two validators for each aspect. Meanwhile, the instrument for assessing the practicality of teaching materials is compiled in the form of a questionnaire that will be filled out by undergraduate students. The questionnaire consists of 18 statements, covering four aspects: usefulness, the aspect of ease, attractiveness, and efficiency.

4.3 Development and Expert Validation

The development stage concentrated on transforming the results of the needs assessment into a structured, classroom-ready instructional product. Once the initial draft of the Predict, Observe, Explain (POE)-based teaching materials for inferential statistics was completed, a systematic expert validation process was carried out to ensure that the product met high standards of accuracy, pedagogical value, and visual clarity before its application in the classroom.

Two experienced validators were involved in this process. The first was a specialist in content and materials who examined the conceptual accuracy, logical sequence, and pedagogical relevance of the teaching resources. The second was a specialist in display and presentation who focused on layout, visual readability, and design consistency. Each expert applied a structured validation sheet that included seven indicators grouped under two primary dimensions: Material and Content, and Display and Presentation.

The validation process was designed not merely to check factual correctness but to confirm that the teaching materials would function as an integrated and user-friendly tool that guides students step by step through the stages of prediction, observation, and explanation. This emphasis on usability and cognitive scaffolding represents an important move away from traditional text-heavy materials towards an active learning approach that supports reasoning skills. The results of this validation are shown in Table 4.1.

Table 4.1. Validation Results of POE-Based Teaching Materials

Aspect	Indicator	Score	Percentage (%)	Average
Material and Content	Suitability	3.67	91.8	88.3%
	Accuracy	4.00	100	
	Convenience	3.25	81.3	
	Attractiveness	3.50	87.5	
	Completeness	3.25	81.3	
Display and Presentation	Display	3.92	98.0	93.2%
	Function	3.63	90.8	
	Benefits	3.73	90.8	
Overall Average	–	–	–	90.75% Valid

The expert validation produced an overall score of 90.75 percent, classifying the POE-based teaching materials as *Valid*. This strong result reflected high pedagogical coherence, well-organized visuals, and readiness for classroom use after minor revisions. The highest ratings were recorded for Accuracy (100 percent) and Display (98 percent), confirming that the materials were precise in definitions, examples, formulas, and statistical procedures, and that their visual layout effectively guided students. Lower scores for Convenience and Completeness (81.3 percent each) highlighted sections that needed clearer navigation and more comprehensive coverage of subtopics, particularly in the one-way testing section, which was later restructured with explicit sub-points and improved example problems.

The validation results underscored the alignment between conceptual accuracy and instructional design. While the perfect accuracy and strong display scores demonstrated that the materials conveyed correct statistical knowledge in an appealing way, the lower scores for convenience and completeness revealed that technical correctness alone does not guarantee usability. The feedback emphasized that students need materials that are not only accurate but also organized in ways that support self-learning and logical reasoning, especially for abstract topics like one-way testing. The average Material and Content score of 88.3 percent confirmed that the core topics in inferential statistics were covered well, yet also suggested room to improve sequencing and scaffolding to enhance students' adaptive reasoning.

Following these refinements, the final product effectively bridged the gap between technical precision and learner-centered design. The improved materials guided students systematically through each stage of the POE approach, enabling them to predict, observe, and explain outcomes with greater clarity and confidence. The validation process demonstrated that high-quality teaching resources must integrate accuracy, clarity, usability, and cognitive accessibility. By addressing these elements, the revised POE-based materials became ready for real classroom application, supporting not only understanding of inferential statistics but also the development of students' logical and adaptive reasoning.

4.4 Small-Group Practicality Trial

Following the expert validation and subsequent revisions, the next crucial phase was to examine how the improved POE-based inferential statistics materials performed in a real classroom context. To achieve this, a small-group practicality trial was conducted with five undergraduate students enrolled in the Mathematics Education program who were currently taking the Educational Statistics course.

The primary aim of this trial was to measure the practicality of the materials before scaling up their use in larger classes. Practicality here referred to how well the materials could be understood, navigated, and applied by students during learning sessions. To collect data, students completed an 18-item practicality questionnaire designed to capture their perceptions across four critical dimensions: usefulness, convenience, attractiveness, and efficiency.

Each dimension provided insight into specific aspects of the learning experience. Usefulness focused on whether the materials supported learning objectives and enhanced students' understanding. Convenience assessed the clarity of instructions, logical structure, and ease of following the activities. Attractiveness referred to the visual appeal, layout, and engagement value of the materials, while efficiency evaluated whether the content could be completed within the expected time frame without unnecessary complexity. The results of this trial are presented in Table 4.2.

Table 4.2. Practicality Results – Small-Group Trial

Aspect	Score	Percentage (%)	Average	Criteria
Usefulness	3.17	79	**80%**	Practical
Convenience	3.24	81		
Attractiveness	3.27	82		
Efficiency	3.13	78		

The small-group trial produced an overall practicality score of 80 percent, classifying the POE-based teaching materials as *Practical* for classroom use. This strong rating showed that the revised materials were user-friendly, easy to navigate, visually appealing, and supportive of students' learning needs. Attractiveness scored highest at 82 percent, indicating that the layout, visuals, and overall design motivated students to engage with the content. Convenience followed at 81 percent, confirming that the sequence of content and instructions was clear and intuitive, while Usefulness scored 79 percent, showing that students found the materials effective for enhancing their understanding of inferential statistics. The lowest score was Efficiency at 78 percent, suggesting that some activities required more time than anticipated.

These results demonstrated that the post-validation revisions effectively addressed earlier gaps. The high ratings for attractiveness highlighted that well-designed visuals and logical layouts encouraged students to engage with abstract concepts, while the clear structure ensured that students could focus on reasoning tasks instead of struggling with navigation. The slightly lower efficiency score revealed that some prediction, observation, and explanation tasks needed more time than typically available in class. This finding suggested that minor pacing adjustments could better align the materials with standard classroom schedules.

Overall, the small-group trial confirmed that the POE-based materials were practical, engaging, and effective in supporting students' reasoning development. The results also underscored that practicality involves more than surface-level appeal; it depends on a balance of usability, engagement, and time management. Although efficiency was slightly lower due to the time needed for deeper reasoning, this was not seen as a limitation but as evidence that students were engaged in meaningful cognitive processes. With minor adjustments to pacing or task duration, the materials were deemed ready to be scaled up for larger classes.

4.5 Large-Group Practicality Trial

After the successful small-group trial, the next phase aimed to evaluate the practicality of the Predict, Observe, Explain (POE)-based inferential statistics materials under more realistic classroom conditions. A large-group trial was therefore conducted with 15 undergraduate students enrolled in the Mathematics Education program. This group reflected a typical class size for the Educational Statistics course and allowed for a better assessment of how the materials would function in a standard instructional setting.

The trial was implemented over five instructional meetings that integrated the POE-based materials into actual lesson delivery. The objectives of this phase were to determine whether the materials remained practical in a larger learning environment, to evaluate student engagement at scale, and to identify any new challenges related to time management or classroom dynamics.

The same 18-item practicality questionnaire used in the small-group phase was administered again to assess four critical dimensions: usefulness, convenience, attractiveness, and efficiency. These dimensions provided a consistent measure to compare the practicality outcomes between the small-group and large-group trials. The results of the large-group practicality trial are summarized in Table 3.

Table 3. Practicality Results – Large-Group Trial

Aspect	Score	Percentage (%)	Average	Criteria
Usefulness	3.12	78	77.6%	Practical
Convenience	3.16	79		
Attractiveness	3.22	81		
Efficiency	2.91	73		

The large-group trial achieved an overall practicality score of 77.6 percent, which remained within the *Practical* category despite being slightly lower than the small-group score of 80 percent. This result showed that the POE-based teaching materials retained their effectiveness and usability even in a larger classroom setting. Attractiveness scored highest at 81 percent, followed by Convenience at 79 percent and Usefulness at 78 percent, indicating that students continued to appreciate the logical structure, clear presentation, and appealing visual design of the materials. Efficiency scored the lowest at 73 percent, reflecting that some tasks required more time to complete in a larger group environment.

The slight decline in overall practicality highlighted the effect of class size on instructional dynamics. Although the materials maintained their clarity, usefulness, and engagement, time management became a greater challenge in the large-group setting. The lower efficiency score was primarily due to longer discussions, the need to address more student questions, and additional time required to coordinate collaborative activities. Nevertheless, the consistently high ratings in attractiveness and convenience confirmed that the design and layout remained robust, and students continued to find the materials valuable for understanding inferential statistics.

These findings affirmed that the POE-based materials are adaptable for typical classroom environments while revealing that reasoning-oriented learning often requires more time for in-depth discussion and problem-solving. The reduced efficiency score was not a weakness but evidence of meaningful student engagement in reflective and collaborative reasoning. To maximize classroom efficiency without reducing learning depth, instructors may adjust pacing, streamline certain activities, or allocate extra sessions. Overall, the large-group trial demonstrated that the POE-based teaching materials can be successfully scaled up for broader use, continuing to support students' adaptive reasoning while maintaining quality and engagement across different class sizes.

4.6 Insight from Classroom Implementation

The classroom observations combined with feedback from both students and lecturers provided valuable insights into how the Predict, Observe, Explain (POE)-based inferential statistics materials functioned during actual teaching sessions. These findings reveal not only the strengths of the developed materials but also practical considerations for future improvements. The following points highlight the most significant findings observed during implementation, along with their broader educational implications.

These key findings collectively show that the POE-based teaching materials achieved their primary goal of improving inferential statistics learning by combining validated content, practical usability, and active learning strategies. The materials not only proved valid in design but also demonstrated their practicality and positive impact in real classroom conditions.

The evidence of enhanced engagement and strengthened adaptive reasoning suggests that integrating POE into mathematical instruction can transform the learning experience from procedural training to conceptual mastery. The identified need for time-management adjustments highlights that deeper reasoning often demands more classroom time, an investment that appears justified given the observed cognitive benefits.

In conclusion, these findings affirm that the POE-based approach is effective in bridging the gap between computational accuracy and conceptual reasoning in statistics education. The lessons learned from classroom implementation provide valuable insights for further refinement, ensuring that future iterations balance depth of learning with classroom efficiency while sustaining student engagement and reasoning development.

4.6.1. High Validity of Content and Design

The expert validation process that resulted in a score of **90.75 percent** confirmed that the teaching materials were accurate, pedagogically coherent, and effectively structured. This high level of validity indicates that the instructional content aligned well with inferential statistics learning objectives while presenting the material in a format that supported students' reasoning processes. The validated design ensured that each component, from textual explanations to sample problems, reinforced conceptual understanding rather than simply delivering computational procedures.

This finding highlights that rigorous validation is crucial in educational material development, as it guarantees that students encounter content that is both trustworthy and aligned with desired learning outcomes. It also demonstrates the success of integrating pedagogical design principles into mathematical instruction to address reasoning challenges in statistics education.

4.6.2. Practicality in Real-Class Use

The small-group trial (80 percent) and the large-group trial (77.6 percent) both confirmed that the materials were practical and well-received by students across different class sizes. Students reported that the structure and instructions of the materials were clear and intuitive, allowing them to navigate the lessons without confusion.

This result indicates that the design features refined during the development and validation stages translated effectively into practical classroom application. It also reflects the importance of providing logical sequencing and user-friendly layouts, especially for subjects that often intimidate learners, such as statistics.

4.6.3. Positive Engagement through POE Stages

One of the most notable classroom observations was the positive student engagement with the structured steps of prediction, observation, and explanation. Students were enthusiastic about the activities, which encouraged them to think critically, test their assumptions, and discuss findings with peers. This engagement was visible in their willingness to participate in problem-solving tasks and their improved ability to explain reasoning processes aloud.

The strong engagement suggests that the POE approach successfully shifted learning from passive reception of information to active participation in reasoning. It also underscores the value of interactive and inquiry-oriented learning methods in fostering deeper conceptual understanding in mathematics-related subjects.

4.6.4. Improved Adaptive Reasoning

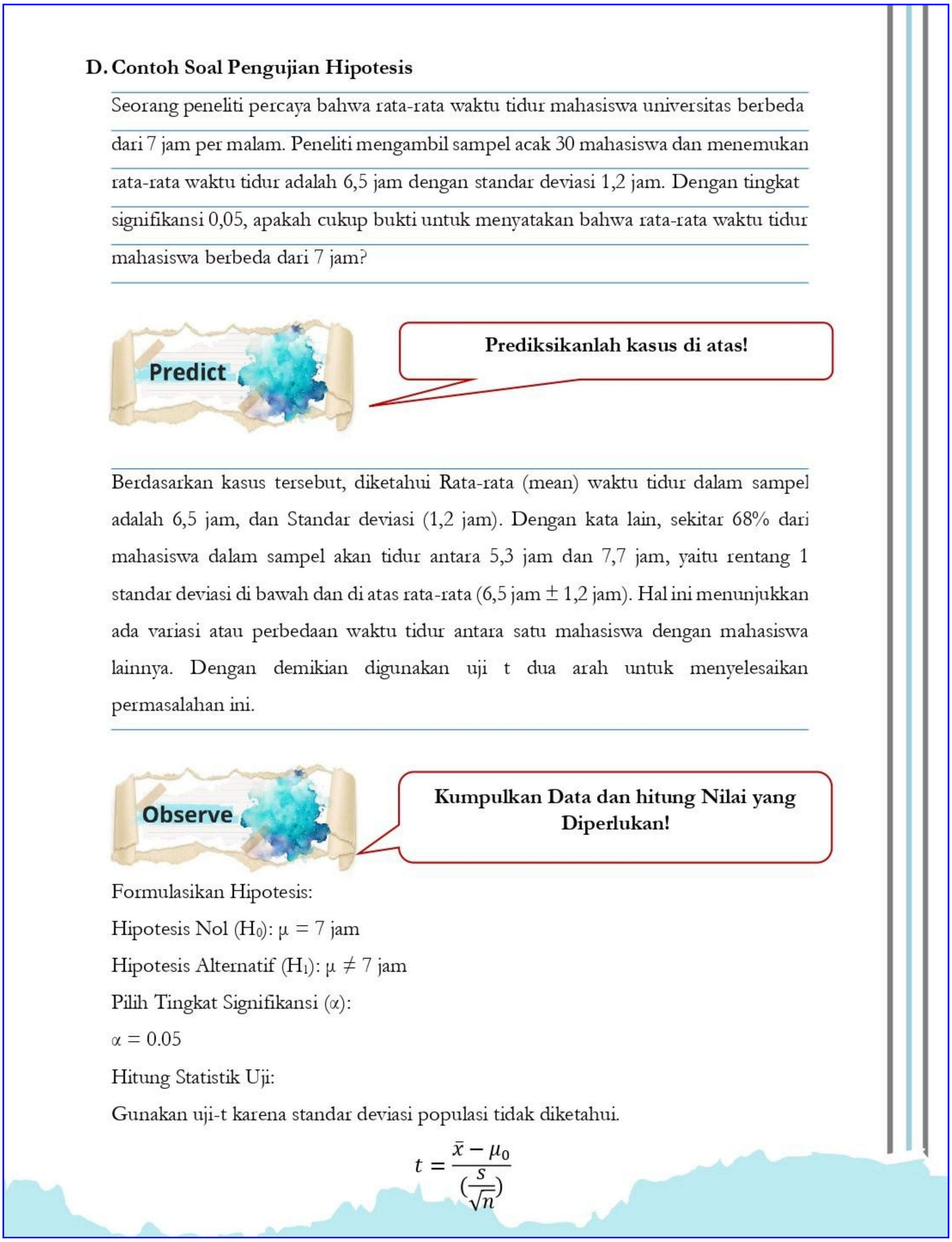
The classroom implementation showed marked improvement in students' adaptive reasoning skills**.** Through the POE-based activities, students practiced articulating hypotheses, justifying statistical conclusions, and linking computational steps to logical explanations. These cognitive behaviors indicate the successful development of higher-order reasoning skills rather than mere memorization of procedures. This finding is particularly important because it addresses a critical gap in traditional inferential statistics instruction, which often emphasizes formula application at the expense of reasoning. By fostering adaptive reasoning, the materials prepared students to transfer their understanding to unfamiliar problems, which is essential for real-world application of statistical knowledge.

4.6.5. Need for Time-Management Adjustments

While students appreciated the activities, the slightly lower efficiency score**,** especially during the large-group trial, indicated that certain tasks were time-consuming. Activities that required extended group discussion or detailed explanations occasionally exceeded the standard class period. This finding suggests that, although beneficial for reasoning development, some tasks may need streamlining or reallocation of time to maintain smooth classroom pacing. This observation is not necessarily a limitation but rather a sign that the approach promotes in-depth learning that naturally requires more time for discussion and analysis. Future implementations could address this by adjusting the pacing, splitting longer activities across multiple sessions, or providing preparatory materials for students to complete before class.

4.7 Evidence of POE Integration and Student Reasoning

The implementation of the Predict, Observe, Explain (POE) approach was a central feature of the newly developed teaching materials for inferential statistics. The integration of POE was deliberately designed to shift the focus of instruction from memorizing procedures to fostering logical thinking, hypothesis formulation, and reflective reasoning. The evidence of how POE was embedded into the materials and how students responded to it is captured in Figures 1, 2, and 3. The Figures 1 and 2 illustrate how the POE sequence was seamlessly embedded into the structure of the teaching materials.



D. Contoh Soal Pengujian Hipotesis

Seorang peneliti percaya bahwa rata-rata waktu tidur mahasiswa universitas berbeda dari 7 jam per malam. Peneliti mengambil sampel acak 30 mahasiswa dan menemukan rata-rata waktu tidur adalah 6,5 jam dengan standar deviasi 1,2 jam. Dengan tingkat signifikansi 0,05, apakah cukup bukti untuk menyatakan bahwa rata-rata waktu tidur mahasiswa berbeda dari 7 jam?

Predict

Prediksikanlah kasus di atas!

Berdasarkan kasus tersebut, diketahui Rata-rata (mean) waktu tidur dalam sampel adalah 6,5 jam, dan Standar deviasi (1,2 jam). Dengan kata lain, sekitar 68% dari mahasiswa dalam sampel akan tidur antara 5,3 jam dan 7,7 jam, yaitu rentang 1 standar deviasi di bawah dan di atas rata-rata (6,5 jam ± 1,2 jam). Hal ini menunjukkan ada variasi atau perbedaan waktu tidur antara satu mahasiswa dengan mahasiswa lainnya. Dengan demikian digunakan uji t dua arah untuk menyelesaikan permasalahan ini.

Observe

Kumpulkan Data dan hitung Nilai yang Diperlukan!

Formulasikan Hipotesis:

Hipotesis Nol (H_0): $\mu = 7$ jam

Hipotesis Alternatif (H_1): $\mu \neq 7$ jam

Pilih Tingkat Signifikansi (α):

$\alpha = 0.05$

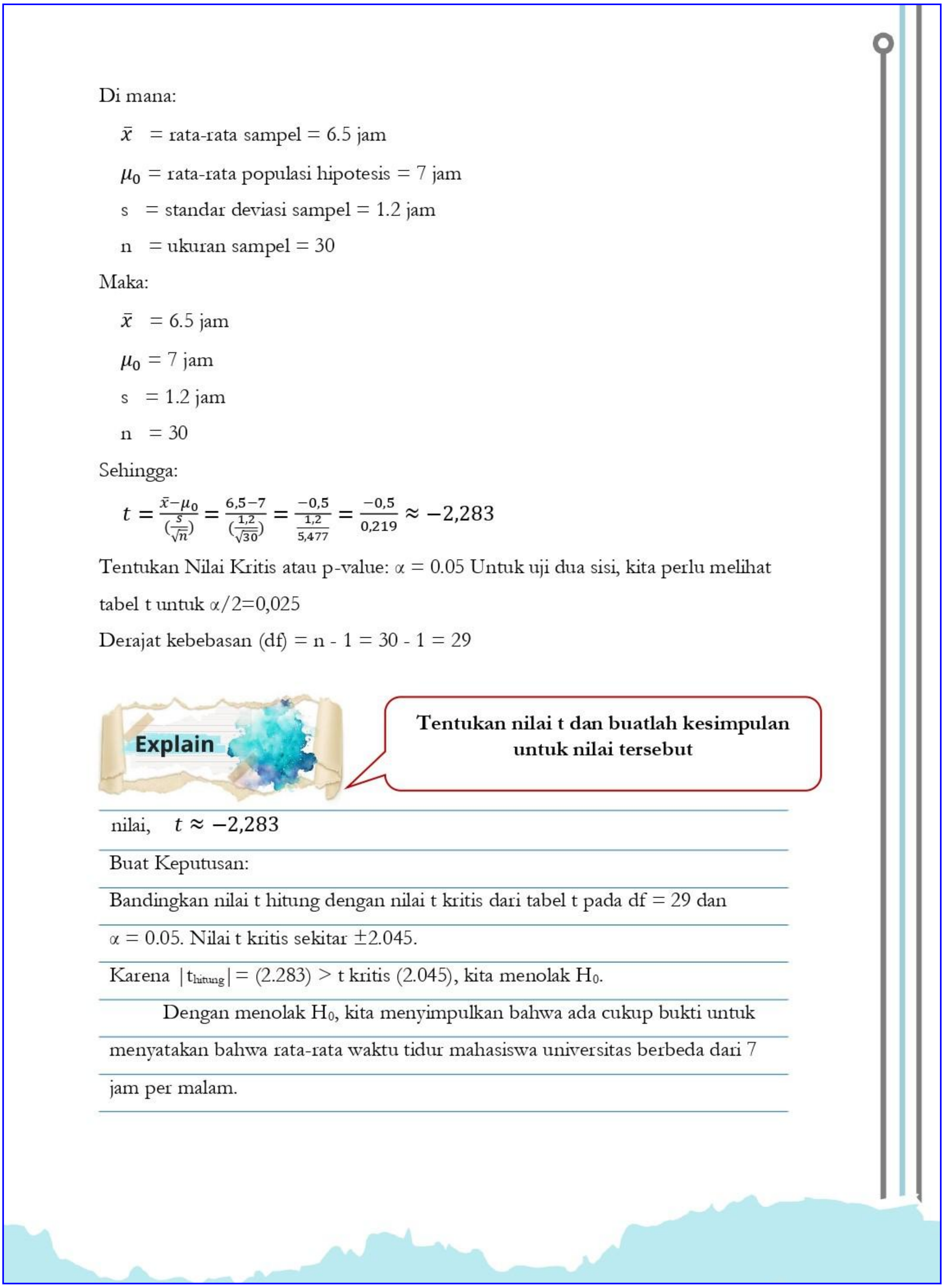
Hitung Statistik Uji:

Gunakan uji-t karena standar deviasi populasi tidak diketahui.

$$t = \frac{\bar{x} - \mu_0}{(\frac{s}{\sqrt{n}})}$$

Figure 1: Integration of POE in Teaching Material – Predict and Observe Stage

This figure showcases how students were encouraged to begin each activity by making predictions about the outcome of a statistical problem before conducting any calculations. This stage required them to connect their prior knowledge with the problem scenario and articulate an informed expectation of the result. Once the prediction was made, students proceeded to the observation phase, where they engaged with the actual data and conducted statistical analyses to test their initial assumptions.



Di mana:

$\bar{x}$ = rata-rata sampel = 6.5 jam

μ_0 = rata-rata populasi hipotesis = 7 jam

s = standar deviasi sampel = 1.2 jam

n = ukuran sampel = 30

Maka:

$\bar{x}$ = 6.5 jam

μ_0 = 7 jam

s = 1.2 jam

n = 30

Sehingga:

$$t = \frac{\bar{x}-\mu_0}{\left(\frac{s}{\sqrt{n}}\right)} = \frac{6,5-7}{\left(\frac{1,2}{\sqrt{30}}\right)} = \frac{-0,5}{\frac{1,2}{5,477}} = \frac{-0,5}{0,219} \approx -2,283$$

Tentukan Nilai Kritis atau p-value: $\alpha = 0.05$ Untuk uji dua sisi, kita perlu melihat tabel t untuk $\alpha/2 = 0,025$

Derajat kebebasan (df) = n - 1 = 30 - 1 = 29

Tentukan nilai t dan buatlah kesimpulan untuk nilai tersebut

nilai, $t \approx -2,283$

Buat Keputusan:

Bandingkan nilai t hitung dengan nilai t kritis dari tabel t pada df = 29 dan $\alpha = 0.05$. Nilai t kritis sekitar ± 2.045.

Karena $|t_{hitung}| = (2.283) > t$ kritis (2.045), kita menolak H_0.

Dengan menolak H_0, kita menyimpulkan bahwa ada cukup bukti untuk menyatakan bahwa rata-rata waktu tidur mahasiswa universitas berbeda dari 7 jam per malam.

Figure 2: Integration of POE in Teaching Material – Observe and Explain Stage

This figure highlights the transition from observation to explanation. After analyzing the data, students were guided to interpret the patterns they observed and to explain their findings by justifying whether the evidence supported or contradicted their predictions. This stage encouraged reflective thinking and helped students link computational outcomes to conceptual reasoning.

Together, these figures demonstrate that the teaching materials were not merely a collection of exercises but an interactive guide that led students through a logical and structured learning cycle. The inclusion of stepwise instructions at each stage ensured that students were consistently applying the three phases of POE, which deepened their understanding of inferential statistics concepts such as hypothesis testing and sampling distributions.

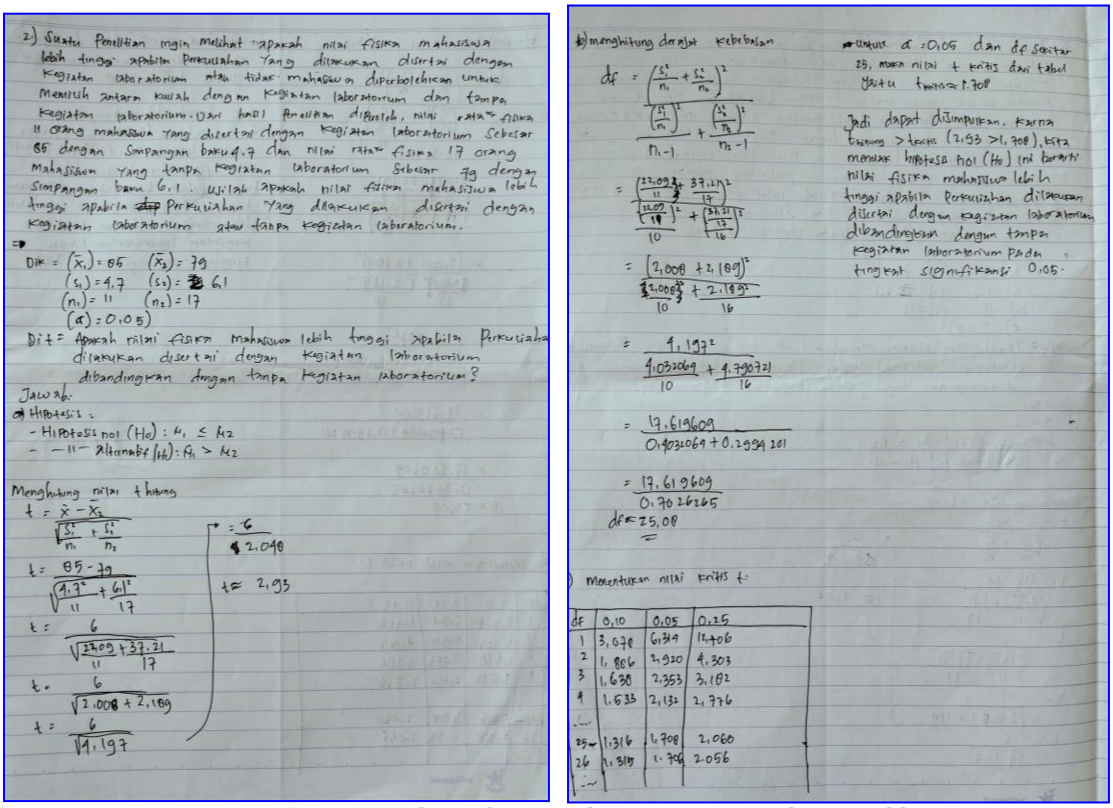


Figure 3. Undergraduate Student Answers in Solving Problems

Figure 3 presents a compelling example of how the POE-based approach shaped students' reasoning in solving a comparative-means hypothesis-testing problem. The student's written response provides a clear sequence of cognitive steps:

1) Formulating a Hypothesis: The student began by articulating both the null and alternative hypotheses, showing an ability to translate the problem statement into a statistical framework.
2) Computing Test Statistics: The student then calculated the test statistic and the degrees of freedom accurately, demonstrating procedural competence and attention to detail.
3) Drawing a Conclusion: Finally, the student interpreted the computed values, compared them against critical thresholds, and derived a conclusion consistent with statistical evidence.

This written solution highlights the way POE-based tasks encouraged students to organize their thinking in a logical manner, progressing from assumption to evidence and then to judgment. The student's reasoning process reveals that the materials effectively supported adaptive reasoning by prompting them to justify every step rather than simply performing computations.

The integration of POE into the teaching materials had a clear and positive impact on how students approached statistical problem-solving. Three key findings emerged:

1) Structured Learning Pathway: The POE sequence provided a scaffolded approach that helped students' progress logically from conceptual prediction to empirical validation and reflective explanation.
2) Enhanced Conceptual Linkages: By requiring students to make predictions and revisit them during explanation, the materials promoted stronger connections between theoretical concepts and real-world data analysis.
3) Evidence of Deep Reasoning: Students' written responses, such as the example in Figure 3, demonstrated that they were not only able to carry out mathematical computations but also able to explain their reasoning and support their conclusions with evidence.

The evidence presented in these figures illustrates that integrating POE into statistical teaching materials can transform the nature of classroom learning. Rather than viewing statistical formulas as abstract rules, students began to see them as tools for testing hypotheses and interpreting data-driven evidence. This shift from procedural to conceptual thinking is a critical step toward building higher-order reasoning skills.

Moreover, the written solution in Figure 3 highlights how students internalized the habit of linking their predictions with the observed outcomes. This reflective practice strengthened their metacognitive awareness, allowing them to monitor their own understanding and adjust their reasoning strategies as needed. Such skills are vital not only for mastering inferential statistics but also for tackling complex, open-ended problems in other academic and professional contexts.

The visual evidence and classroom examples demonstrate that the POE-based approach served as a bridge between abstract statistical theory and practical reasoning. The structured prompts to predict outcomes before observing and explaining results encouraged students to engage actively with the problem, rather than passively following formulas.

This evidence also highlights that students developed adaptive reasoning by learning to justify their conclusions with statistical evidence. Instead of treating results as fixed numerical answers, they recognized the importance of supporting their decisions with data and logical argumentation. This represents a significant advancement over traditional teaching methods, which often prioritize computational accuracy without fostering the capacity to reason through complex problems.

In conclusion, Figures 1, 2, and 3 provide compelling proof that the integration of POE in the teaching materials transformed learning into a more interactive and reflective process. These findings underscore the effectiveness of the POE approach in nurturing critical thinking, improving conceptual comprehension, and developing adaptive reasoning skills that are essential for success in inferential statistics.

5. Discussion

The study confirmed that the Predict, Observe, Explain (POE)-based teaching materials for inferential statistics were both valid and practical, achieving an overall expert validation score of 90.75 percent and practicality ratings of 80 percent in small-group and 77.6 percent in large-group trials. The highest indicators of quality were Accuracy (100 percent) and Display (98 percent), showing that the materials provided precise statistical concepts with clear visual presentation. The lower but still strong indicators of Convenience and Completeness (81.3 percent) pointed to the importance of structuring examples and instructions for more intuitive use. Classroom trials further highlighted positive student engagement, enhanced adaptive reasoning, and the recognition of a need for time-management adjustments in larger classes.

The high validity score of 90.75 percent obtained in this study confirms that the POE-based teaching materials successfully combined rigorous statistical content with pedagogically sound instructional design. This finding shows that it is possible to achieve both conceptual accuracy and cognitive accessibility within a single instructional product (Kilpatrick et al., 2001; France & Krievina, 2022). This alignment reflects an essential principle in mathematics education, which emphasizes that effective teaching materials should not only present correct concepts but also facilitate learners' ability to reason adaptively and apply those concepts in solving problems. The combination of accuracy and scaffolding is crucial because students in statistics education often excel in applying formulas but encounter difficulties in reasoning and understanding the underlying concepts (Lestari et al., 2022; Sari, 2017).

The positive practicality ratings observed in both the small-group trial with 80 percent and the large-group trial with 77.6 percent provide further evidence that the developed materials were designed to be accessible and user-friendly. The clear layout, logical sequencing of activities, and structured presentation of content helped reduce unnecessary cognitive load, allowing students to focus on reasoning tasks rather than struggling to navigate the learning materials. This finding supports the importance of student-centered learning environments where clarity of design contributes directly to deeper engagement and understanding (Davies, 2011; Noor et al., 2023).

The strong ratings for attractiveness, which reached 82 percent in the small-group trial and 81 percent in the large-group trial, confirm that a well-structured visual design can motivate students to engage with abstract and challenging topics such as hypothesis testing, correlation, and regression analysis. These findings are consistent with earlier studies that emphasized the role of organized presentation and visual quality in promoting effective learning in mathematics education (Cahyadi, 2019; Kristanto et al., 2017).

The results also align with a growing body of evidence demonstrating that POE-based instructional strategies foster deeper learning by encouraging active participation, reflective thinking, and meaningful collaboration. Previous studies consistently reported that well-structured POE materials improve critical thinking skills, conceptual understanding, and problem-solving abilities across science and mathematics contexts (Amahoru et al., 2023; Arslan & Emre, 2020; Çalış & Özkan, 2022).

The present study extends these findings into the context of inferential statistics in higher education. The structured cycle of predicting outcomes, observing empirical evidence, and explaining the results provided a coherent framework for bridging the long-recognized gap between procedural computation and conceptual reasoning (Fitrianingsih et al., 2021; Murtihapsari et al., 2022; Kumlu & Şahin, 2022). This contribution is particularly significant because traditional lecture-based approaches often fail to help students connect formulaic computation with the logical interpretation of statistical findings (Aouaf et al., 2023; Lestari et al., 2022).

A particularly important finding from the classroom implementation was the improvement in adaptive reasoning skills among the participating students. Adaptive reasoning, which enables students to justify their conclusions and apply knowledge to new situations, is a higher-order competency that supports lifelong learning in data-driven disciplines (Jatisunda et al., 2024; Ansari et al., 2020). The design of the teaching materials, which embedded prediction tasks requiring students to articulate initial assumptions and encouraged them to revisit these assumptions in the explanation phase, strengthened their metacognitive awareness. Such awareness is critical for developing evidence-based decision-making skills in statistical reasoning and for building logical connections between prior knowledge and new concepts (Kumlu & Şahin, 2022; Segerby & Chronaki, 2018; Keiler et al., 2017; Kim et al., 2019).

The slightly lower efficiency ratings, with 78 percent in the small-group trial and 73 percent in the large-group trial, highlight a natural tension between the depth of reasoning-oriented activities and the limited time available during regular class sessions. This finding is consistent with earlier studies that noted inquiry-based and discussion-oriented approaches often require additional instructional time to allow students to explore discrepancies between predictions and observations and to engage in meaningful reflection and explanation (Segerby & Chronaki, 2018; Suryamiati et al., 2019; Ilma et al., 2022). Although this longer time requirement might be perceived as a limitation, it reflects the cognitive investment needed for students to engage in higher-order reasoning and to strengthen their conceptual understanding.

These results suggest that creative pacing strategies could address the challenge of limited class time without reducing the quality of reasoning development. Such strategies may include assigning selected POE prediction tasks as preparatory work before class, dividing more complex activities into shorter sessions, or integrating blended learning tools to maximize in-class discussion time.

Overall, the findings of this study show that POE-based teaching materials, when rigorously validated and thoughtfully designed, can transform the teaching of inferential statistics by shifting the focus from mechanical memorization of formulas to conceptual reasoning and reflective problem-solving. The evidence further highlights that integrating well-organized design elements and flexible pacing is critical to realizing the full pedagogical benefits of reasoning-oriented instructional approaches.

Despite its positive outcomes, this study highlights several gaps. First, it was limited to undergraduate students from a single institution, which restricts generalizability to other academic levels or broader populations (Lestari et al., 2022). Second, the study focused primarily on short-term outcomes, improvements in reasoning observed during classroom implementation, leaving the long-term impact of POE-based materials on retention and transfer of reasoning skills unexplored. Third, while the study measured practicality and reasoning development, it did not assess affective factors such as students' attitudes toward statistics or their anxiety levels (Yahya et al., 2024), which could significantly influence learning outcomes.

The novelty of this research lies in expanding the Predict–Observe–Explain (POE) approach, which has been widely applied in science education, to the context of higher-level inferential statistics with a specific emphasis on strengthening adaptive reasoning. This study shows that the structured phases of prediction, observation, and explanation within the POE model can effectively bridge abstract statistical concepts with practical reasoning skills, thereby supporting deeper conceptual understanding and flexible problem-solving in statistical learning.

The findings carry significant implications for curriculum designers and educators in mathematics education. First, they suggest that reasoning-focused learning materials can elevate students' ability to justify conclusions rather than merely calculate results, which is critical for evidence-based decision-making in academic and professional fields (Kim et al., 2019; Vetten et al., 2018). Second, the study underscores the importance of integrating cognitive scaffolding and visual design to support learners' comprehension of abstract concepts, addressing barriers identified in previous research (Feronika et al., 2023; France & Krievina, 2022). Lastly, this approach aligns with global educational priorities for fostering critical thinking, problem-solving, and data literacy as core competencies for twenty-first-century learning (Keiler et al., 2017).

Future research should involve multiple institutions and more diverse student populations in order to evaluate the scalability of POE-based materials across various contexts and educational levels.

Longitudinal investigations are also needed to assess the long-term effects of POE on adaptive reasoning, knowledge retention, and knowledge transfer. In addition, incorporating affective dimensions such as student motivation, statistical anxiety, and attitudes toward reasoning would provide a more comprehensive understanding of how POE contributes to learning outcomes. Researchers may also extend this line of inquiry by developing digital versions of POE-based learning materials, including interactive e-books or gamified learning platforms, to enhance engagement and accessibility (Çırakoğlu et al., 2022; Nazliati et al., 2024), to enhance engagement and accessibility in blended or online learning environments.

6. Conclusions

This study developed and validated POE-based teaching materials for inferential statistics through the systematic stages of the Hannafin and Peck model, encompassing needs assessment, design, development, and implementation. The materials demonstrated high validity, with an overall score of 90.75 percent, comprising 88.3 percent for content and material quality and 93.2 percent for presentation and visual design. Practicality was also confirmed, with ratings of 80 percent in the small-group trial and 77.6 percent in the large-group trial, indicating that the materials were pedagogically coherent, visually accessible, and effective for classroom use. The integration of the POE approach significantly enhanced students' adaptive reasoning by encouraging them to predict, observe, and explain statistical outcomes in a structured manner, thereby transforming learning from procedural application toward conceptual understanding.

The novelty of this study lies in extending the POE framework, traditionally applied in science education, into the abstract and underexplored context of university-level inferential statistics, with a specific emphasis on cultivating adaptive reasoning. The findings carry important implications for curriculum development and instructional practice, as they highlight the potential of validated, student-centered learning materials to foster deeper engagement, strengthen reasoning skills, and support the cultivation of twenty-first century competencies such as critical thinking, problem-solving, and data literacy. Future research is recommended to examine the long-term effects of POE-based instruction on reasoning retention and knowledge transfer, to investigate its adaptability across diverse educational levels and institutional contexts, and to integrate affective dimensions such as motivation and statistical anxiety. Further exploration of digital and blended-learning adaptations, including interactive e-modules and gamified platforms, may also enhance the accessibility and scalability of POE-based resources in contemporary higher education settings.

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