Journal on Mathematics Education
Volume 16, No. 3, 2025, pp. 915-936

Seeing data differently: Developing a local instructional theory for culturally relevant statistical literacy in Indonesian teacher education

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Received: 17 April 2025 | Revised: 18 August 2025 | Accepted: 20 August 2025 | Published Online: 23 August 2025

Abstract

Statistical literacy has emerged as a central competence in mathematics education, particularly for prospective teachers who must be able to interpret, analyze, and critically evaluate data in a world increasingly shaped by information and statistics. However, previous research shows that many prospective teachers continue to struggle with developing statistical literacy, especially in connecting abstract concepts to meaningful contexts. This gap highlights the need for instructional designs that not only strengthen statistical reasoning but also draw on culturally embedded practices to enhance relevance and engagement. Addressing this challenge, the present study develops a Local Instructional Theory (LIT) that supports prospective teachers' statistical literacy through the integration of local cultural contexts in South Sumatra, designed within the framework of Realistic Mathematics Education (RME) as adapted in Indonesia, namely *Pendidikan Matematika Realistik Indonesia* (PMRI). Employing a design research methodology, the study was conducted in three phases: a preliminary investigation, a design experiment (pilot and teaching experiment), and a retrospective analysis. The resulting LIT was structured around three context-based learning trajectories, each targeting a key dimension of statistical literacy: data visualization, data interpretation, and critical evaluation. Instructional activities were grounded in authentic cultural contexts—such as *Pempek* demand during Ramadan, the *Bekarang Iwak* fishing tradition, and coffee productivity in Pagar Alam—which were used to bridge statistical concepts with learners lived experiences. Findings from the teaching experiments indicate that prospective teachers demonstrated notable shifts from procedural to conceptual reasoning and from descriptive analysis to reflective critique. Participants also showed improved ability to select appropriate graphical representations, interpret contextual data, and critically assess the credibility and sufficiency of statistical information. These outcomes underscore the potential of culturally relevant instructional design to foster holistic statistical literacy. The study contributes both theoretically and practically by offering a validated model for integrating cultural contexts into mathematics education, thereby enriching prospective teachers' curriculum and providing a replicable approach for diverse educational settings.

Keywords: Design Research, PMRI, Prospective Teachers, South Sumatra Context, Statistical Literacy

How to Cite: Utari, R. S., Putri, R. I. I., Zulkardi, & Hapizah. (2025). Seeing data differently: Developing a local instructional theory for culturally relevant statistical literacy in Indonesian teacher education. *Journal on Mathematics Education, 16*(3), 915–936. https://doi.org/10.22342/jme.v16i3.pp915-936

Statistical literacy has become increasingly critical in today's data-driven society, enabling individuals to recognize and interpret the abundance of data present in everyday life and to critically analyze it across domains such as healthcare, business, politics, social sciences, and education (Gal, 2019). Amid the rapid growth of information, statistical literacy equips individuals with the skills necessary to make informed decisions, assess probabilities, and evaluate risks in daily contexts (François et al., 2020; Monteiro & Carvalho, 2023). For prospective teachers, statistical literacy is particularly essential, as it allows them to guide students in interpreting data, developing critical thinking skills, and navigating misinformation in the digital era (Gunawan et al., 2023; Kus & Çakiroglu, 2020). Within teacher education, statistical literacy further supports educators in analyzing student learning outcomes, implementing data-driven instruction, and responding effectively to the evolving demands of contemporary curricula (Peedikayil et al., 2023).

Despite its importance, research consistently indicates that many prospective teachers encounter difficulties in understanding statistical concepts (Forgasz et al., 2024). Empirical studies reveal that they often struggle with grasping foundational statistical ideas, interpreting data accurately, and applying statistical reasoning in educational contexts (Johannssen et al., 2021; Kalobo, 2016). These challenges highlight the need for instructional approaches that enhance prospective teachers' conceptual understanding and enable meaningful application of statistics.

One promising approach is Local Instructional Theory (LIT), which provides a systematic framework for designing contextualized and meaningful statistical learning experiences (Bakker, 2018; Gravemeijer & Cobb, 2006). LIT structures learning sequences by considering how statistical concepts are introduced, comprehended, and applied across diverse educational contexts, thereby fostering deeper and more transferable understanding (van Dijke-Droogers et al., 2022). By encouraging prospective teachers to move beyond superficial interpretations and critically engage with data, LIT facilitates the reconstruction of their statistical knowledge in ways that are closely connected to real-world experiences. Although LIT has been widely implemented in mathematics education, its potential for promoting statistical literacy—particularly among prospective teachers—remains underexplored (Büscher, 2022; Sharma, 2017). Consequently, further investigation of LIT in statistics education is warranted to optimize prospective teachers' learning experiences and professional preparedness.

A complementary pedagogical framework is Realistic Mathematics Education (RME), which addresses both content knowledge (understanding statistical concepts) and pedagogical knowledge (designing meaningful learning experiences) (van Dijke-Droogers et al., 2022). In Indonesia, RME has been adapted to the local context and is referred to as *Pendidikan Matematika Realistik Indonesia* (PMRI) (Zulkardi et al., 2020). PMRI emphasizes the use of authentic, real-world contexts in mathematics instruction, including statistics, to connect abstract concepts with learners lived experiences (Meitrilova & Putri, 2020; Rahayu & Putri, 2020). Unlike approaches that rely on generic or decontextualized problems, PMRI integrates Indonesian cultural traditions, local practices, and daily life into learning tasks (Fauziah et al., 2020; Putri et al., 2015; Utari et al., 2024a), thereby rendering statistical concepts more tangible and relevant.

In statistics education, PMRI facilitates the goal of enabling students and prospective teachers to "see data differently" by situating statistical concepts within their cultural and experiential realities. For example, Ramadhani et al. (2024) demonstrated that a descriptive statistics instructional design using the traditional food *Lemang Batok* Bamboo, combined with scaffolded discussions, enhanced students' abilities to organize data, interpret distributions, and engage in critical and analytical thinking. Similar studies show that context-based approaches not only connect statistics to everyday life but also promote deeper statistical reasoning and reflective engagement with data.

The context-driven approach of PMRI aligns with Gal's (2019) emphasis on situating statistical literacy within real-world contexts. Gal asserts that statistical education should encompass domains where individuals encounter and interact with statistical information, including media, the workplace, everyday life, and personal or social decision-making (Sharma, 2017). Accordingly, statistical understanding depends not only on mathematical concepts and procedures but also on the capacity to interpret, evaluate, and critically apply data within relevant contexts (Phadke, 2022). Furthermore, Waard et al. (2021) highlight the pivotal role of context in both individual and societal data-driven decision-making. Integrating Gal's contextual emphasis with the structured learning design of LIT positions PMRI as a pedagogical bridge that connects statistical concepts with learners' cultural realities, thereby enhancing prospective teachers' statistical literacy.

Utari et al. (2024b) further illustrate the potential of embedding local wisdom in statistical literacy education. Their study identifies six characteristics that make local wisdom contexts effective in instruction: (1) integration of South Sumatra's local wisdom, (2) meaningfulness to students, (3) significance to students, (4) active student engagement, (5) enhancement of students' capacity to discuss civic statistics and social implications, and (6) seamless integration of statistical scenarios into learning activities. Building on these insights, this study adopts these six characteristics as design principles for developing instructional tasks within a LIT framework that incorporates South Sumatra's cultural context.

By integrating LIT with PMRI, statistical learning becomes both culturally and contextually relevant, while remaining structured to support prospective teachers in interpreting data through cultural lenses. This approach fosters engagement, critical thinking, and deeper understanding. While LIT offers a framework for sequencing learning experiences (Bakker, 2018; Gravemeijer & Cobb, 2006), PMRI situates statistical concepts within meaningful contexts (Sharma, 2017). Prior studies have demonstrated PMRI's effectiveness in enhancing students' statistical understanding (van Dijke-Droogers et al., 2022); however, research examining PMRI within LIT frameworks to specifically support prospective teachers' statistical literacy remains limited. Addressing this gap, the present study aims to develop a Local Instructional Theory that integrates South Sumatra's cultural contexts to strengthen prospective teachers' statistical literacy and prepare them for effective teaching practice.

METHODS

This study employs a design research approach, specifically a validation study, to formulate a LIT that can be iteratively developed and refined during implementation (Bakker, 2018). LIT refers to an empirically grounded instructional theory that emerges from the iterative process of designing and implementing instruction for a specific topic—in this study, statistics. It delineates the anticipated learning trajectory, patterns of students' reasoning shifts, and the mechanisms used to support and organize the learning process, including sequences of activities, supporting tools (e.g., digital media), and the teacher's role (Doorman, 2005). LIT encompasses a set of provisional learning activities and predicted learning processes aimed at forecasting how students' understanding and reasoning evolve as activities are enacted in the classroom (Gravemeijer & Cobb, 2006).

This research comprises three main phases: (1) preliminary research, (2) design experiment, and (3) retrospective analysis (Bakker, 2018; Gravemeijer & Cobb, 2006). The following sections provide a detailed description of each phase.

Preliminary Research

In the preliminary phase, several steps were undertaken to establish the foundation for the instructional design. First, a comprehensive literature review was conducted on statistical literacy, the PMRI approach, and the integration of local contexts in mathematics education. Second, an exploratory study examined the potential of South Sumatra's local contexts—such as statistical data from the Central Bureau of Statistics and cultural practices, for example, the *Bekarang Iwak* tradition—to support statistical literacy.

Data for this exploratory study were collected through document analysis of statistical reports and interviews with local stakeholders, facilitating the identification of authentic and meaningful contexts. Insights from this exploration informed the selection of statistical topics, including descriptive statistics (e.g., measures of central tendency) and inferential statistics (e.g., correlation and regression).

Each Hypothetical Learning Trajectory (HLT) was constructed using the PMRI framework, incorporating phases such as the situational stage, model-of (where students construct models based on concrete situations), model-for (where models are generalized to broader mathematical ideas), and formalization (where concepts are connected to formal mathematics). The HLTs include clearly defined learning objectives, planned learning activities, and anticipated cognitive processes that prospective teachers are expected to experience during instruction. Table 1 presents an overview of the instructional design for statistical literacy.

Table 1. The learning design in statistics topic

Learning Steps	Context	Learning Objectives	Learning Activities	Thinking & Learning Process	Statistics' Content
Data visualization	Demand and sales of *Pempek* during Ramadan in Palembang	Prospective teachers can represent and interpret data using appropriate visualization	Prospective teachers reading, understand and organize statistical data on Pempek demand and production. Then create graphs	Identifying relevant variables, organizing data, and selecting suitable visualization techniques.	Statistics descriptive
Data interpretation & analysis	*Bekarang Iwak* Tradition	Prospective teachers can analyze relationship between two variables using correlation analysis	Prospective teachers examine data on fish catch result and environmental factors, then compute and interpret correlation coefficients.	Understanding relationship between variables, recognizing patterns, and interpreting statistical results.	Statistics inference (Correlation)
Critical evaluation of statistical information	Coffee production in Pagar Alam	Prospective teachers can critically evaluate statistical models and their implication on real-world contexts.	Prospective teachers assess the accuracy and limitation of a regression model predicting coffee production trends, considering external factors such as climate change and market demand.	Evaluating the validity of statistical findings, identifying potential biases or misinterpretations, and making data driven decisions.	Statistics inference (Simple regression)

Design Experiment

The design experiment phase aimed to test and iteratively refine the HLTs developed during the preliminary research through two cycles: a pilot experiment and a teaching experiment. In the pilot experiment, a small group of ten prospective teachers with varying mathematical abilities participated in classroom activities designed according to the HLTs. Data were collected through classroom observations, video recordings, students' written worksheets, and researcher field notes. These data were analyzed qualitatively to compare the anticipated learning processes with the Actual Learning Trajectories (ALTs). Insights from this analysis informed revisions to the learning activities, enhancing clarity, coherence, and alignment with the intended learning objectives.

The second cycle, the teaching experiment, implemented the revised HLTs in a larger cohort of fifty prospective teachers. This cycle aimed to examine the effectiveness of the refined learning design in a broader classroom context and to collect comprehensive data on prospective teachers' engagement with statistical tasks grounded in local cultural contexts. During this phase, data were collected via video recordings of all classroom sessions, students' written work, and audio recordings of class discussions. While data collection occurred concurrently, the analysis of learning processes, students' reasoning, and development of statistical literacy was conducted during the subsequent retrospective analysis phase.

Retrospective Analysis

In the retrospective analysis phase, researchers compared the initial HLTs with the ALTs that emerged from both the pilot and teaching experiments. The analysis drew on prospective teachers' written work, classroom video recordings, and field notes to identify patterns in their thinking and learning. Particular attention was given to how participants engaged with statistical concepts in descriptive and inferential statistics through culturally relevant contexts, including *Pempek* demand and sales during Ramadan, the *Bekarang Iwak* tradition, and coffee production in Pagar Alam. This process enabled the researchers to trace the development of prospective teachers' reasoning, from informal interpretations toward more formal statistical understanding. The findings informed the refinement of the learning trajectory and the formulation of a LIT that integrates culturally meaningful activities to support the development of statistical literacy among prospective teachers.

RESULTS AND DISCUSSION

This study developed a LIT to support the statistical literacy of prospective teachers by integrating local cultural contexts from South Sumatra. Rather than focusing on a single Learning Trajectory (LT), the LIT incorporates three interrelated LTs, each addressing a core aspect of statistical literacy: data visualization, data interpretation and analysis, and critical evaluation of statistical information. This approach aligns with Gravemeijer and Van Eerde (2009), who argue that an LIT may involve multiple learning trajectories, depending on the complexity of the instructional domain. By incorporating multiple LTs, the instructional design becomes more comprehensive and systematic, reflecting the multidimensional nature of statistical literacy. Each LT was developed in accordance with PMRI principles, progressing from culturally contextualized activities toward formal statistical understanding.

This article synthesizes a larger doctoral research project, portions of which—each focusing on a specific learning trajectory—have already been published or are under review in peer-reviewed journals. Consequently, this article presents the overall design experiment and its outcomes while consolidating the findings into a unified LIT that supports statistical literacy through culturally relevant pedagogical approaches.

Preliminary Study

The study began with a literature review on frameworks of statistical literacy (Callingham & Watson, 2017; Gal, 2019), PMRI principles and characteristics (van den Heuvel-Panhuizen et al., 2014; Zulkardi et al., 2020), and the role of local contexts in meaningful mathematics learning (Rawani et al., 2023; Utari et al., 2024a). To identify appropriate cultural entry points, data from the Central Bureau of Statistics were analyzed alongside field observations in South Sumatra. This process led to the selection of three culturally relevant contexts: seasonal demand and sales of Pempek during Ramadan in Palembang, the *Bekarang Iwak* fishing tradition, and coffee production trends in Pagar Alam.

Preliminary validation involved expert reviews and Focus Group Discussions (FGDs) with mathematics education lecturers, practitioners, students, and PMRI-based instructional design specialists. Feedback from these sessions informed revisions to the initial HLTs and prospective teachers' worksheets. Additionally, informal needs assessments conducted through interviews with university lecturers highlighted common challenges students face in understanding statistical concepts and connecting them to culturally familiar contexts. The final HLTs were structured according to PMRI instructional phases—situational, model-of, model-for, and formalization—ensuring a coherent progression from contextual engagement to formal statistical reasoning. Figure 1 illustrates this trajectory, emphasizing how South Sumatran cultural elements support the development of statistical literacy.

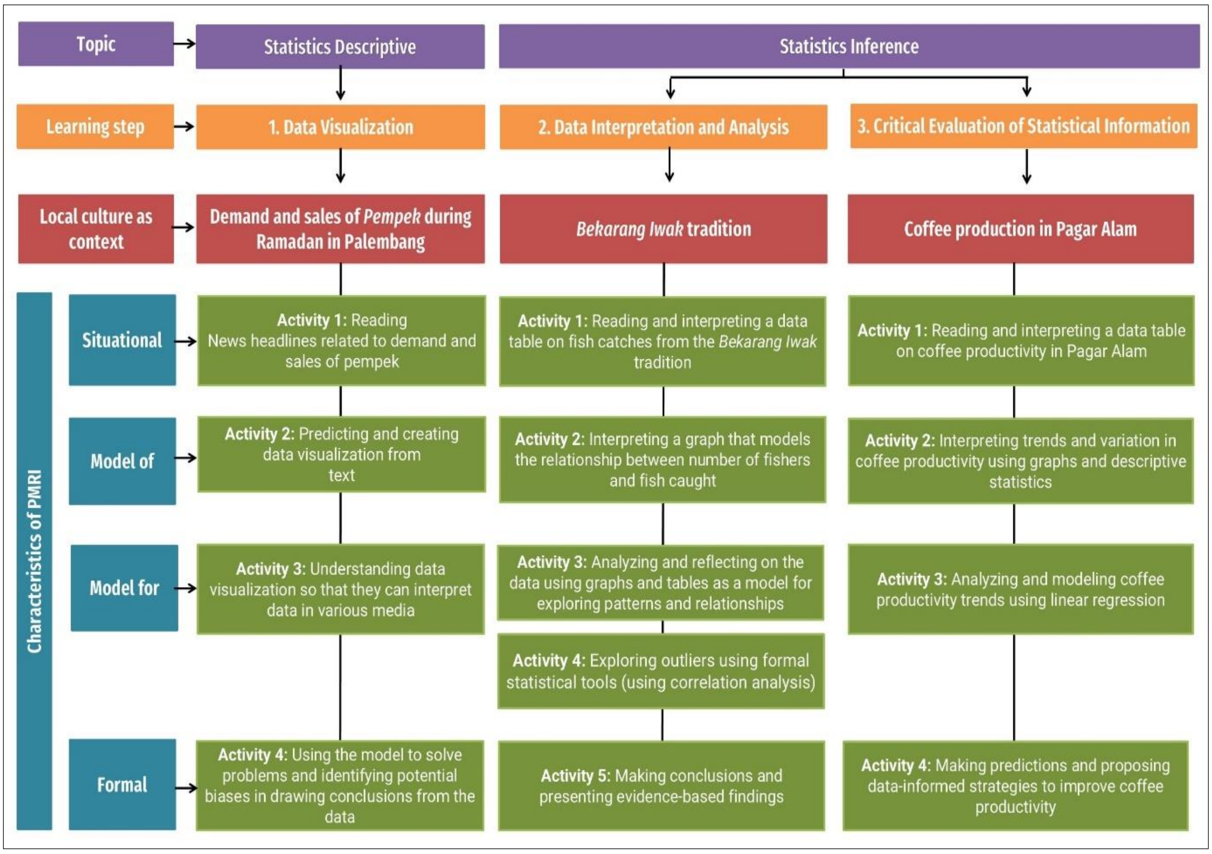

Figure 1. PMRI-based learning trajectory integrating South Sumatra culture

Figure 1 presents a PMRI-based learning trajectory that integrates local cultural contexts to enhance statistical literacy among prospective teachers. Grounded in PMRI principles, the trajectory begins with authentic, meaningful situations, guiding learners toward abstract statistical understanding. Contexts such as *Pempek* sales during Ramadan, traditional *Bekarang Iwak* practices, and coffee production patterns serve as familiar starting points, enabling learners to construct informal models. These models then evolve into formal statistical concepts through tasks focused on data visualization, interpretation, analysis, and critical evaluation. This culturally responsive approach enhances cognitive engagement and ensures that learning is both relevant and authentic. As Bakker (2004) and Gal (2019) emphasize, real-world contexts are essential for fostering deep and transferable statistical understanding. By embedding learning within local knowledge and practices, this trajectory cultivates robust, socially grounded statistical literacy.

Design Experiment

The pilot experiment phase was conducted with ten prospective teachers to explore the sequencing of activities within each LT and to examine the alignment between the initial design predictions and the actual reasoning and responses of participants. This phase focused on prospective teachers' engagement with locally contextualized activities and aimed to identify unexpected strategies, misconceptions, or gaps in understanding. Data collected through classroom observations, student responses, and discussions revealed that some activities were either overly challenging or lacked sufficient scaffolding. For example, during visual data tasks, some students prioritized aesthetic elements over accurate representation, whereas in interpretation tasks, many relied on intuition rather than systematic statistical reasoning.

Based on these findings, several revisions were made prior to the teaching experiment phase, which involved fifty prospective teachers from the same semester but in different classes. Revisions included clarifying instructions, reordering activities to better align with PMRI principles (from situational to formal), and incorporating bridging tasks to support the transition from informal to formal understanding. The revised activities were then implemented in the teaching experiment to validate these improvements and to systematically trace students' learning progression.

Learning Trajectory: Visualizing Data in the Context of Pempek Demand and Sales During Ramadan

The pilot experiment demonstrated the potential of integrating statistical content with local cultural contexts, particularly through the exploration of Pempek consumption and sales during Ramadan in Palembang. The instructional sequence began with a culturally grounded question posed by the lecturer: "*Do you like eating Pempek?*"—a traditional South Sumatran dish familiar to all participants. All prospective teachers responded affirmatively, establishing a shared cultural reference point. The lecturer then asked, "*When is the right time to eat Pempek?*" eliciting responses that reflected enthusiasm and familiarity with the cultural context, including occasions ranging from breakfast to social events.

To guide the discussion toward statistical reasoning, the lecturer introduced the question: "*Do you know how many Pempek are sold by vendors during the month of Ramadan? Do you think the sales are the same as on regular days?*" This line of inquiry anchored early statistical engagement in a culturally meaningful context and provoked curiosity about data variation influenced by socio-cultural and religious traditions. The opening activity involved reading news articles related to Pempek sales during Ramadan, serving as a situational anchor rooted in prospective teachers lived experiences. While this activity successfully generated initial interest in engaging with real-world data, classroom observations indicated that engagement remained largely procedural. Most participants focused on converting textual information into graphical representations, such as bar charts or pie charts, without interrogating the underlying meanings, assumptions, or communicative purposes of their visualizations. Consequently, the activity primarily promoted surface-level data representation rather than fostering a deeper understanding of the relationship between data, context, and interpretation. These observations were further corroborated by student responses collected via the Nearpod platform as shown in Figure 2.

	English version:
Produksi pempek pada tahun 2023 menunjukkan pemulihan yang tidak signifikan dibandingkan dengan tahun 2022, karena pada tahun 2023 mengalami penurunan perkiraan 1 ton dibandingkan tahun 2022.	“Pempek production in 2023 showed an insignificant recovery compared to 2022, as there was an estimated decrease of 1 ton in 2023 compared to 2022.”
Jika berkaca pada produksi tahun 2022,mungkin jumlah produksi per hari tahun 2023 tidak terlalu mengalami pemulihan yang signifikan karena menurut perkiraan tadi 18 ton, namun tahun 2023 hanya 17 ton jadi mungkin tidak naik alias turun menurut perkiraan nya.	“Reflecting on the 2022 production, the daily production in 2023 may not have experienced a significant recovery, as the earlier estimate was 18 tons, while in 2023 it was only 17 tons—so it might not have increased, but rather decreased according to the estimate”
Tidak signifikan, dalam teks disebutkan produksi pempek mengalami kenaikan menjadi 17 ton per hari. Sementara pada tahun sebelumnya disebutkan adanya kenaikan 50% dari tahun 2021.	“Not significant—the text mentioned that Pempek production increased to 17 tons per day. Meanwhile, the previous year saw a 50% increase from 2021”.

Figure 2. Examples of descriptive interpretation from prospective teachers during the pilot experiment

Figure 2 illustrates that when prospective teachers were prompted to analyze data on Pempek production in 2023, they relied almost exclusively on textual information to draw conclusions. Their responses primarily reflected descriptive interpretations, such as noting that production had “*not recovered*,” “*declined by 1 ton*,” or “*did not show significant change*,” without reference to underlying trends, variability, or graphical representations. Several examples revealed that students drew conclusions directly from the article’s narrative, without employing data modeling or comparing multiple data points over time. These observations suggest a critical gap in the transition from descriptive to analytical reasoning, indicating that participants had not yet internalized the use of statistical tools to support evidence-based interpretation.

These findings indicate that while contextual anchoring effectively engaged students, it did not, by itself, cultivate a deeper level of statistical literacy. The initial learning trajectory was structured according to PMRI characteristics, progressing through four instructional stages: situational (contextual engagement), model-of (graph construction), model-for (interpretation of external visualizations), and formal (problem-solving and bias detection). Although this sequence provided coherent pedagogical flow and maintained contextual relevance, it lacked sufficient conceptual depth and opportunities for exploratory thinking—both of which are essential for developing robust statistical reasoning. In response, the learning trajectory was refined and re-implemented during the teaching experiment phase to better support analytical thinking and conceptual understanding, as depicted in Figure 3.

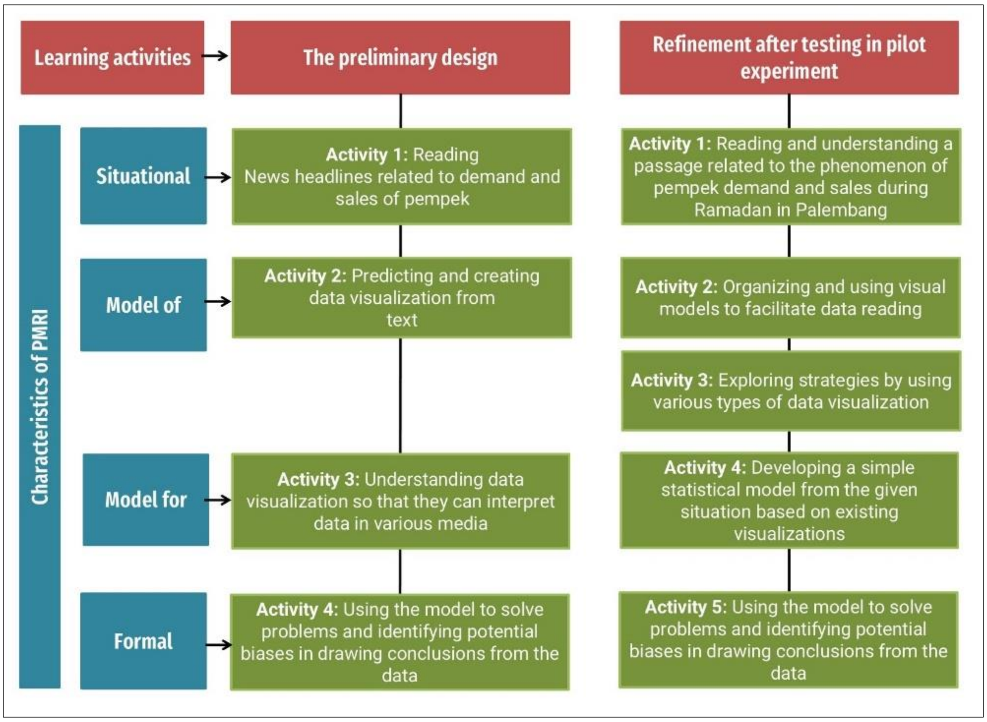

Figure 3. Refinement of the learning trajectory for data visualization

Figure 3 showed that the refinements led to notable improvements in both engagement and statistical thinking. In Activity 3 (model-of), the instructional sequence was extended to encourage exploration of multiple visualization types, enabling prospective teachers to compare and evaluate graph formats based on both data characteristics and communicative clarity. Activity 4 (model-for) incorporated the development of simple statistical models, facilitating meaningful connections between contextual information, visual representations, and formal statistical concepts. Activity 5 (formal) continued to emphasize problem-solving and bias identification, with enhanced reasoning observed as participants began to justify their visualization choices and critically reflect on potential misinterpretations of the data.

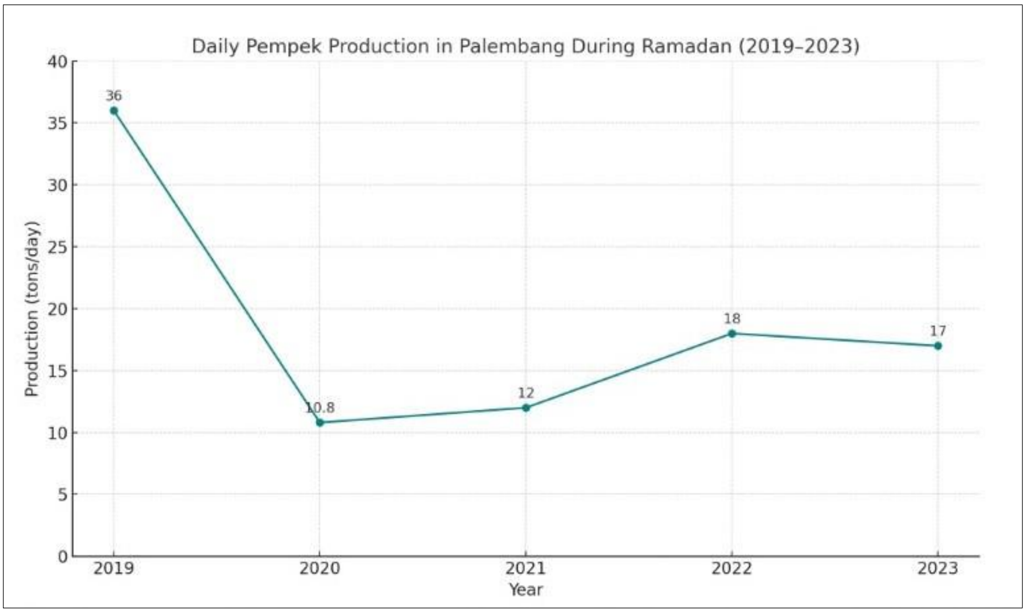

Figure 4. Prospective teachers' visualization using line graph

Figure 4 illustrates an example response produced by a prospective teacher during Activity 4, in which they selected a line graph as the most appropriate visualization to model the growth of Pempek sales during Ramadan. This choice reflects a shift toward more deliberate and statistically grounded reasoning, as the line graph allowed the participant to identify trends over multiple years, evaluate rates of change, and detect fluctuations associated with socio-cultural disruptions, such as the COVID-19 pandemic. By linking the visualization to contextual narratives, the prospective teacher demonstrated an enhanced ability to construct and interpret statistical models meaningfully within the local context.

This improvement in reasoning is further supported by an excerpt from a small-group interview between the lecturer and participants, highlighting how their thinking evolved in selecting appropriate visual representations:

L : *"Why did you choose a line graph to represent the data?"*
PT1 : *"It helps us see how sales changed from year to year. It's clearer for showing trends."*
L : *"PT2, do you agree with this choice? Why not use something like a bar chart? Or pie diagram?"*
PT2 : *"A bar chart could work, but I think the line graph shows the overall movement better. You can see the sharp drop in 2020 and how it slowly rises again."*
L : *"Interesting. PT3, what do you think is the main takeaway from this visualization?"*
PT3 : *"For me, it's how external factors like the pandemic affected local food sales. A line graph helps connect the numbers to real events."*
L : *"So, you're all saying that the line graph isn't just about showing numbers, but also telling a story?"*
PT1 : *"Yes, exactly."*

This dialogue demonstrates how the lecturer facilitated prospective teachers in articulating their choices of data visualization by integrating statistical reasoning with contextual understanding. Through guided prompts that encouraged participants to justify their selections and consider alternative representations, the discussion promoted deeper reflection on the communicative purposes of graphical displays. Additionally, Activity 3 played a pivotal role in supporting the development of prospective teachers' statistical literacy. By engaging participants in evaluating the appropriateness of different diagram types, this activity enhanced their ability to reason with data, make informed representational decisions, and communicate statistical information effectively within meaningful, culturally relevant contexts.

Learning Trajectory: Data Analysis and Interpretation through the Context of Bekarang Iwak

This learning trajectory, grounded in PMRI principles and local cultural knowledge, was designed to support prospective teachers in analyzing and interpreting data through the *Bekarang Iwak* tradition—a communal fish-catching event in South Sumatra. The trajectory was developed iteratively using a design research approach, beginning with a pilot experiment and subsequently refined through a teaching experiment.

The instructional sequence commenced with culturally grounded questions, such as, "*Have you ever participated in a community fish-catching event in your village?*" These questions elicited enthusiastic discussions and strong cultural connections, establishing a foundation for contextualized statistical inquiry. The first activity required prospective teachers to interpret real-world data tables derived from interviews with local leaders detailing fish catches over multiple years.

During the pilot phase, while some participants identified key data points, many struggled with comparing data and interpreting trends. Nearpod reports indicated that 40% of prospective teachers either did not complete the task or misinterpreted the data. In response, instructional revisions were implemented, including the addition of guiding questions, extended discussion time, and scaffolding for graph construction. These modifications produced substantial improvements in the teaching experiment. Approximately 88% of prospective teachers successfully completed the task, employing statistical language such as average, fluctuation, and contextual reasoning. For example, one participant noted, "*Even though more people joined in 2022, the total catch decreased—possibly because the pond was too shallow*" as shown in Figure 5. This response illustrates the integration of statistical concepts with contextual understanding and highlights the trajectory's effectiveness in fostering analytical reasoning within a culturally meaningful framework.

	English version:
Ada, jika jumlah dari penangkap ikan naik maka hasil tangkapan ikan juga naik. Begitu pula sebaliknya.	"There is [a relationship], if the number of fish catchers increases, the fish catch also increases. And vice versa."
Ada hubungan, jadi jika jumlah penangkap ikannya banyak maka hasil tangkapan ikannya juga banyak, sebaliknya jika jumlah penangkap ikan lebih sedikit maka jumlah ikan yang didapat juga akan lebih sedikit.	"There is a relationship, so if the number of fish catchers is high, then the fish caught will also be many. Conversely, if the number of fish catchers is low, the number of fish caught will also be less."
Ada memiliki pola yaitu pola penurunan, semakin banyak jumlah penangkap ikan maka semakin banyak pula jumlah hasil dari tangkapan ikan, begitu pula sebaliknya. Iya ada memiliki hubungan yaitu hubungannya berbanding lurus	"There is a pattern, namely a declining pattern. The more fish catchers there are, the fewer fish are caught, and vice versa. Yes, there is a relationship, and it is an inverse relationship."
Ada, yakni semakin banyak jumlah penangkap ikan, maka akan semakin banyak pula jumlah hasil tangkapan ikan. Kedua hal tersebut saling berhubungan karena mempengaruhi naik turunnya jumlah hasil tangkapan ikan.	"Yes, the more fish catchers, the more fish will be caught. Both are related because they influence the increase and decrease in the number of fish caught."
ada, semakin banyak jumlah penangkap ikan maka semakin banyak pula hasil tangkapan ikan nya, begitupun sebaliknya. Jadi, jumlah penangkap ikan mempengaruhi jumlah tangkapan ikan nya.	"Yes, the more fish catchers there are, the more fish will be caught, and vice versa. So, the number of fish catchers affects the number of fish caught."
Ada, terdapat hubungannya yaitu polanya semakin banyak jumlah penangkapan ikan maka hasil tangkapannya juga banyak. Terdapat hubungannya yaitu dimana penangkap ikan mempengaruhi hasil jumlah tangkapannya. Jadi, dapat disimpulkan bahwa penangkap dan hasilnya saling berhubungan	"Yes, there is a relationship, the pattern is that the more fish catchers there are, the greater the fish catch. There is a relationship where the number of fish catchers affects the fish catch. So it can be concluded that the number of catchers and the result are related."
ada, yakni semakin banyak penangkap ikan, semakin banyak pula hasil tangkapan. begi	"Yes, the more fish catchers, the more fish caught."
Ada. Pola nya adalah semakin banyak penangkap ikan maka akan semakin banyak pula jumlah tangkapan ikan. Begitupun sebaliknya. Dapat disimpulkan kedua hal tersebut saling berhubungan karena banyak nya penangkap ikan mempengaruhi banyak hasil tangkapan	"Yes. The pattern is that the more fish catchers there are, the more fish will be caught. And vice versa. It can be concluded that both are related because the number of fish catchers influences the number of fish caught."

Figure 5. Early reasoning patterns in student interpretations of contextual data

Figure 5 presents a range of prospective teachers' written responses as they interpreted the relationship between the number of fishers and the number of fish caught in the *Bekarang Iwak* tradition. The responses indicate that most participants recognized a positive correlation, noting that an increase in the number of fishers generally corresponds to a larger catch. Some responses extended beyond descriptive observations, articulating causal reasoning, such as the idea that more people working collectively leads to a higher total yield. Others demonstrated emerging statistical thinking, including the use of comparative language and references to observable patterns or trends. Collectively, these responses illustrate how culturally contextualized data tasks can foster both intuitive and formal reasoning among prospective teachers.

During the second phase (model-of), prospective teachers constructed graphs representing the relationship between the number of participants and the quantity of fish caught. Initially, many assumed a linear correlation; however, peer discussions and prediction exercises revealed more complex patterns. This understanding facilitated progression to the third phase (model-for), where participants began modelling the data using correlation analysis in Excel. With scaffolding, they transitioned from descriptive explanations to calculating and interpreting correlation coefficients. As illustrated in Figure 6, one group identified a strong positive correlation of 0.98 between the number of fishers and total catch, which they used to justify a recommendation to increase participant numbers while simultaneously acknowledging the importance of sustainable practices.

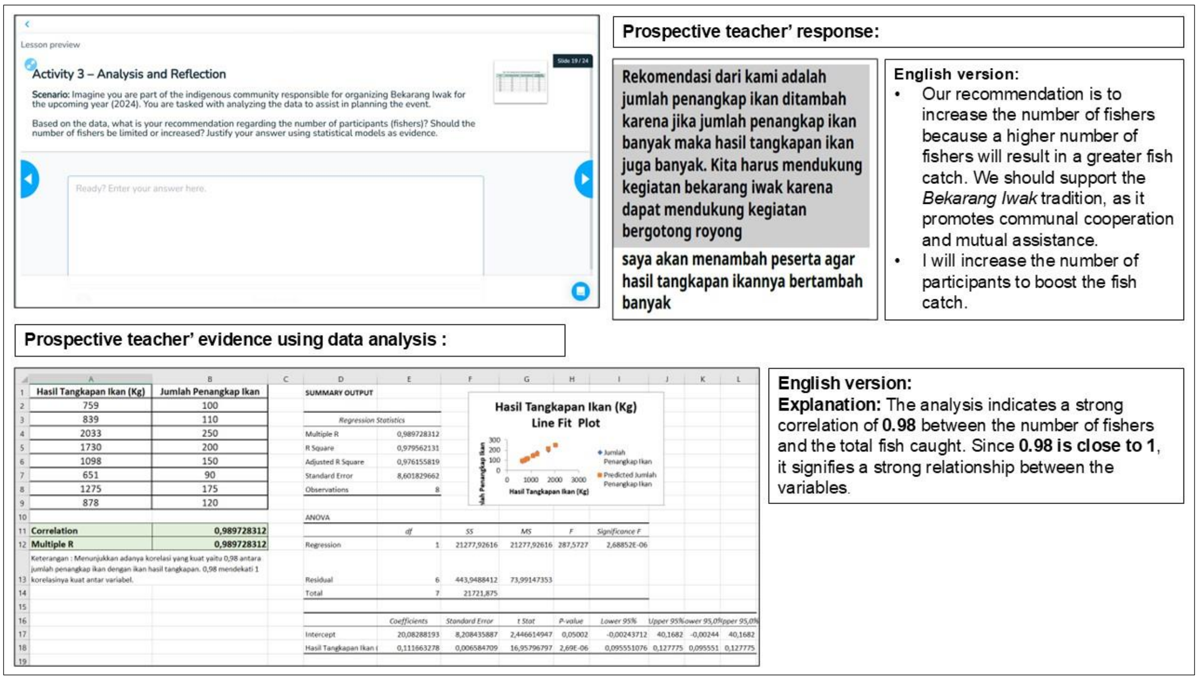

Figure 6. Prospective teachers' recommendation and statistical justification using correlation analysis

The trajectory continued into the formal phase, where prospective teachers applied statistical tools, such as z-scores, to detect outliers. In the final synthesis phase, they drew conclusions and communicated evidence-based recommendations. By the conclusion of the trajectory, participants were able to integrate tables, graphs, and statistical models to justify their interpretations and propose sustainable practices for managing the *Bekarang Iwak* tradition. This five-phase trajectory—(1) situational, (2) model-of, (3) model-for, (4) formal, and (5) formal synthesis—demonstrates how embedding statistical tasks in culturally relevant contexts can deepen prospective teachers' reasoning, with each phase strengthened through iterative design.

Learning Trajectory: Critical Evaluation of Statistical Information through the Context of Coffee Productivity in Pagar Alam

The third learning trajectory was developed to cultivate statistical literacy among prospective teachers, with a focus on the critical evaluation of statistical information. This trajectory is grounded in the local context of coffee productivity in Pagar Alam, South Sumatra—an economically and culturally significant regional activity. In accordance with PMRI principles, the trajectory situates statistical learning within meaningful, context-rich situations that reflect the lived experiences and local realities of prospective teachers. The trajectory comprises four sequential activities designed to develop prospective teachers' ability to critically assess data and draw evidence-based conclusions.

In the first activity, participants explored a dataset representing yearly coffee productivity (in kg/ha) across five districts in Pagar Alam over five years. They classified variables, distinguished between qualitative and quantitative data, and evaluated which data were most relevant for statistical analysis. This stage promotes critical data awareness, encouraging participants to consider both the availability and adequacy of the data, as well as its potential limitations. In the second activity, prospective teachers calculated the mean and standard deviation of productivity data for each district and interpreted these measures in terms of yield stability and variability. This task encouraged participants to move beyond mere computation, engaging in contextual interpretation and connecting statistical measures to local agricultural practices and environmental conditions.

The third activity introduced regression modeling to identify trends and make predictions. Prospective teachers constructed linear models for productivity trends in selected districts and reflected on model fit and limitations. This activity positioned participants to critique the application of statistical models in real-world contexts, question underlying assumptions, examine residuals, and recognize the bounded validity of predictions. Furthermore, in the fourth and final activity, participants formulated data-based recommendations for improving coffee productivity in Pagar Alam. They were required to justify their proposals using evidence from prior analyses. This phase emphasized the role of statistical reasoning in evidence-based decision making and highlighted the utility of statistics for addressing societal and economic challenges.

Prospective teachers' written responses across these activities indicate emerging competencies in both interpretive and evaluative aspects of statistical literacy. For example, Figure 7 illustrates a participant's critical assessment of data relevance in Activity 1, noting the absence of altitude information—an important factor influencing coffee productivity. This observation reflects an awareness of data completeness and contextual relevance, demonstrating the integration of statistical reasoning with local knowledge.

Figure 7 presents a selection of written responses from prospective teachers during Activity 1 of this learning trajectory, in which they were asked to describe trends in coffee productivity across several districts in Pagar Alam from 2016 to 2020. This task was designed to engage participants in the early stages of critical data evaluation by prompting them to interpret multi-year productivity trends and assess potential fluctuations.

The responses reflect a range of observations and interpretations. Many prospective teachers noted a general increase in productivity from 2016 to 2018, followed by a notable decline in 2019 and a partial recovery in 2020. Several participants demonstrated awareness of district-level differences, while others proposed explanations or hypotheses related to agricultural conditions. For example, one participant identified 2019 as a year of "drastic decline almost reaching 50%" in certain districts, indicating careful attention to the data. Another highlighted that the trend was not uniform, noting that although 2018 showed significant increases, 2019 experienced simultaneous decreases across all districts. These responses illustrate early engagement with critical data evaluation and the ability to recognize both temporal patterns and spatial variability, foundational skills in statistical literacy.

Figure 7. Prospective teachers' interpretations of trends in coffee productivity

These insights indicate that prospective teachers were able to identify temporal patterns and recognize anomalies within the data, suggesting an emerging ability to contextualize statistical information rather than merely summarizing numerical changes. Some responses further alluded to potential causes of variation, such as climate conditions or farming practices, reflecting the PMRI emphasis on connecting mathematical reasoning to real-world and locally meaningful contexts. The variation in responses also highlights differences in levels of sophistication in statistical thinking, ranging from surface-level trend identification to deeper analyses involving rates of change and consideration of data limitations. Consequently, this activity served as a diagnostic window into prospective teachers' initial capacities to interpret and critically evaluate data prior to engaging with more advanced statistical modeling in subsequent activities of the trajectory.

Figure 8 presents data on coffee plantation areas and production volumes across five sub-districts of Pagar Alam City from 2016 to 2020, accompanied by trend graphs for three key sub-districts: Dempo Selatan, Dempo Tengah, and Dempo Utara. The data reveal a general increase in production through 2018, followed by a sharp decline in 2019 and a modest recovery in 2020. These fluctuations are also reflected in the standard deviation values, with particularly high variability observed in Dempo Selatan and Pagar Alam Selatan, indicating inconsistent production across years. This visualization provided prospective teachers with a tool for critical evaluation, enabling them to compare regional trends, analyze variability, and draw conclusions that could inform evidence-based decisions or local policy considerations.

These findings suggest that the designed trajectory effectively supports the development of critical evaluation skills by integrating real-world data, local context, and opportunities for modeling and argumentation. The trajectory exemplifies the PMRI principle of vertical mathematization, wherein prospective teachers progressively build and refine mathematical representations to make sense of complex real-world phenomena. The use of a culturally relevant context, such as coffee farming in Pagar Alam, offers a meaningful and motivating environment for statistical inquiry, rendering mathematical thinking visible, purposeful, and socially grounded.

Kecamatan	Komponen Produktivitas Kopi Kota Pagar Alam Menurut Kecamatan										Average	STD
	Luas Kebun (Ha)					Produksi (Ton)						
	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020		
1. Dempo Selatan	834	763	890	1.179,68	1.180,25	38,37	368,69	3.103,00	1.629,98	1.811,68	1390,344	1228,7952
2. Dempo Tengah	2.970,00	2.967,00	2.970,00	2.559,03	2.560,26	266,89	483,99	6.731,22	3.535,85	3.930,02	2989,594	2686,7141
3. Dempo Utara	2.896,00	2.896,00	2.780,00	2.457,82	2.459,00	75,64	345,35	6.465,00	3.396,01	3.774,59	2811,318	2654,4341
4. Pagar Alam Selatan	809,5	810	810	1.046,73	1.047,24	53,04	1.045,87	2.753,30	1.446,28	1.607,51	1381,2	976,5456
5. Pagar Alam Utara	876	876	880	1.079,73	1.080,25	126,95	1.726,45	2.840,11	1.491,88	1.658,20	1568,718	966,16808
Jumlah	8.385,50	8.312,00	8.320,00	8.323,00	8.327,00	560,89	3.970,25	21.892,63	11.500,00	12.782,00		

Figure 8. Coffee productivity trends across sub-districts of Pagar Alam city

Retrospective Analysis

The development and implementation of three distinct LTs reveal how local contexts, combined with the PMRI approach, can cultivate meaningful pathways for statistical literacy that are mathematically robust and socially and culturally relevant. Each LT was purposefully designed to target a specific dimension of statistical literacy: data visualization, data interpretation and analysis, and critical evaluation of statistical information. Through iterative teaching experiments with prospective teachers, the design-based, contextually grounded learning environment facilitated cognitive shifts—from procedural to conceptual thinking, and from descriptive to reflective reasoning.

The first LT, centered on data visualization in the context of *Pempek* demand during Ramadan, demonstrated the power of graphical representations as tools for data communication. Initially, prospective teachers tended to select graph types arbitrarily, relying on familiar visual forms without assessing their appropriateness for the data or intended message. However, the inclusion of comparative activities and guided group discussions fostered an emergent awareness of the rhetorical function of data visualization—communicating a data-driven narrative. This development was evident in participants' growing ability to interpret sales trends as part of broader social dynamics, including pandemic-related impacts and shifts in consumer behavior.

The second LT, situated in the local tradition of *Bekarang Iwak*, encouraged participants to interpret data across time and within real-life situations. This context effectively fostered meaningful engagement while presenting authentic interpretive challenges. Initially, prospective teachers struggled to connect data across different years and discern emerging patterns. With the incorporation of guiding questions and extended exploration time, their capacity to analyze inter-variable relationships and identify outliers improved significantly. This process exemplifies vertical mathematization, as participants progressed from situational observations to the application of formal statistical models, such as correlation analysis, thereby supporting evidence-informed decision-making.

The third LT, focused on coffee productivity in Pagar Alam, provided a platform for cultivating critical evaluation skills. Here, participants were tasked not only with understanding and describing data but also with assessing the completeness, reliability, and limitations of statistical information. This activity encouraged participants to scrutinize underlying assumptions and consider contextual relevance, including geographic and socio-economic factors. Evidence of cognitive transformation was observed in participants' recognition of missing key variables (e.g., altitude) and in their ability to construct arguments and formulate recommendations based on regression models. Consequently, this LT demonstrated considerable potential for fostering statistical citizenship—the capacity to use data responsibly and reflectively in real-world contexts.

The sequential development and implementation of these three LTs illustrate a continuum of statistical literacy development, spanning representational understanding to reflective, critical thinking. Each local context contributed not only thematic richness but also enhanced the learning trajectory through authentic, meaningful experiences. From the personally familiar visualization of Pempek demand to the collective interpretation of data within the *Bekarang Iwak* tradition, and finally to the ecologically and economically complex analysis of coffee productivity, each context provided a meaningful entry point for the development of holistic statistical literacy.

Integrating Local Contexts and PMRI for Statistical Literacy Development

Findings from the retrospective analysis of the three developed learning trajectories demonstrate that embedding local contexts can progressively foster the development of statistical literacy, consistent with the theoretical framework proposed by Gravemeijer and Cobb (2006) and Gravemeijer and Van Eerde (2009), which emphasize learning design and the processes of horizontal and vertical mathematization within PMRI (van den Heuvel-Panhuizen et al., 2014; Zulkardi et al., 2020).

In the first trajectory, which focused on Pempek demand data, prospective teachers initially engaged in horizontal mathematization by organizing raw sales data into tables and graphs that reflected the real-world context. This engagement later evolved into vertical mathematization as participants abstracted these representations into formal statistical measures, such as mean and median, and reflected on their broader implications. Similarly, in the second trajectory centered on the *Bekarang Iwak* tradition, horizontal mathematization was evident when participants identified relevant variables (e.g., fish catch and environmental factors), which were then vertically mathematized through the computation and interpretation of correlation coefficients. In the third trajectory on coffee production, participants began with informal reasoning about trends and external factors (horizontal), which was progressively formalized into regression models and critical evaluations of assumptions and limitations (vertical). Collectively, these trajectories illustrate how culturally embedded contexts can support both the acquisition of statistical concepts and the construction of meaningful understanding.

The integration of local contexts—such as Pempek demand during Ramadan, the *Bekarang Iwak* fishing tradition, and coffee productivity in Pagar Alam—reinforces arguments by Bakker (2004; 2018) and van Dijke-Droogers et al. (2022) that effective statistical learning designs must facilitate transitions from concrete situations to abstract mathematical representations. In the Pempek task, for example, prospective teachers initially engaged descriptively with news articles, noting statements such as, "*Pempek production in 2023 showed an insignificant recovery compared to 2022, with an estimated decrease of 1 ton*." These responses reflected surface-level interpretation based primarily on textual information. As the activity progressed, participants represented observations in graphical forms—bar charts and line graphs—that enabled temporal comparisons across years. This transition exemplifies horizontal mathematization, as participants moved from informal contextual descriptions to formal statistical models, and vertical mathematization, as they evaluated trends and external factors, such as pandemic-related fluctuations. The Pempek context thus provided a culturally meaningful bridge toward formal statistical reasoning.

Furthermore, these findings align with Büscher (2022), highlighting that statistical literacy development requires learning environments that encourage reflection on data meaning rather than procedural manipulation. In the *Bekarang Iwak* and coffee productivity trajectories, learning activities guided participants to explore inter-variable relationships, employ measures of central tendency and variability, and develop regression-based arguments. For example, in the *Bekarang Iwak* task, some students initially assumed that a greater number of fishers would always yield more fish but later refined their reasoning by analyzing averages and variability across different conditions. These processes reflect a progression from surface-level comprehension to more sophisticated statistical thinking, as described in the developmental stages of statistical literacy by Callingham and Watson (2017).

This study also supports findings by Gunawan et al. (2023) and Forgasz et al. (2024), who highlight the persistent challenges prospective teachers face in critically evaluating statistical information and constructing data-based arguments. However, the present study demonstrates that contextually grounded, PMRI-based instruction can substantially enhance these capacities. For instance, in the coffee productivity task, participants not only interpreted regression results but also questioned data validity and formulated recommendations considering missing but potentially influential variables, such as rainfall patterns, soil fertility, and access to fertilizers. By comparing production fluctuations across villages, participants argued that differences could not be explained solely by the provided numerical variables, illustrating a shift from procedural analysis to critical evaluation of data completeness and contextual relevance. Moreover, these results resonate with Gal (2019) and Johannssen et al. (2021), who argue that modern statistical literacy requires contextualized modeling and critical awareness of data misuse. In the coffee productivity trajectory, participants demonstrated the ability to recognize data limitations and critique statistical representations, reflecting the concept of statistical citizenship described by Monteiro and Carvalho (2023) and François et al. (2020). By embedding culturally relevant contexts, such as Pempek consumption, *Bekarang Iwak*, and coffee farming, this study aligns with research emphasizing culturally responsive approaches within PMRI (Fauziah et al., 2020; Putri et al., 2015; Ramadhani et al., 2024). Such approaches strengthen the connection between mathematics and students lived realities while enhancing motivation and fostering critical reflection.

These findings have implications for curriculum design and teacher education in Indonesia, illustrating how local contexts can be systematically integrated to support the development of both statistical reasoning and reflective, context-aware analysis. Overall, the study contributes to ongoing discourse on expanding PMRI to support the holistic and sustainable development of statistical literacy among prospective teachers, emphasizing the intertwined roles of cultural relevance, contextual engagement, and structured mathematical progression.

CONCLUSION

This study successfully developed a LIT aimed at enhancing prospective teachers' statistical literacy by integrating culturally relevant contexts with the principles of PMRI. The LIT articulates a coherent theory of statistical learning for prospective teachers, structured around three interrelated learning trajectories, namely data visualization, data analysis and interpretation, and critical evaluation of statistical information. Each trajectory is supported by carefully designed, context-based activities, pedagogical tools, and defined teacher roles that facilitate the progression from informal, contextually grounded reasoning to formal, reflective, and evidence-based statistical thinking. The implementation of this LIT demonstrates that culturally embedded instruction can create meaningful pathways for developing statistical literacy, linking conceptual understanding with real-world application.

The study's findings indicate that embedding local cultural contexts from South Sumatra—including the demand for *Pempek* during Ramadan, the *Bekarang Iwak* tradition, and coffee production patterns in Pagar Alam—significantly enhances prospective teachers' engagement and cognitive development. Participants demonstrated the ability to move from descriptive interpretations of data to analytical and critical evaluations, showing evidence of both horizontal and vertical mathematization. This contextually grounded approach not only strengthened their procedural and conceptual statistical knowledge but also promoted reflective and critical reasoning, fostering statistical citizenship by connecting abstract mathematical ideas to socially and culturally meaningful phenomena. These results underscore the value of integrating local contexts in teacher education to cultivate statistical literacy that is both academically rigorous and socially relevant.

Finally, this study is limited in scope, focusing on a specific cultural and geographical context and a selected range of statistical topics. Future research should investigate the scalability and adaptability of the LIT in diverse cultural and educational settings, as well as its effectiveness across a broader spectrum of statistical concepts. Additionally, exploring the integration of digital tools and technology-mediated learning within culturally contextualized statistical instruction may further enhance learning experiences and engagement. Such extensions could inform curriculum design and teacher professional development, contributing to the broader goal of cultivating statistically literate educators capable of fostering critical, reflective, and contextually grounded statistical thinking in their students.

Acknowledgments

The authors gratefully acknowledge the financial support from the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia through the Doctoral Dissertation Research (PDD) Scheme, under Primary Contract No. 090/E5/PG.02.00.PL/2024 and Secondary Contract No. 0016.025/UN9/SB1.LP2M.PT/2024.

Declarations

Author Contribution	:	RSU: Conceptualization, Writing – original draft, Data Curation, and Investigation. RIIP: Conceptualization, Methodology, Writing – review and editing, and Supervision. Z: Conceptualization, Writing – review and editing, Supervision, and Validation. H: Conceptualization, Writing – review and editing, Supervision, and Data Analysis.
Funding Statement	:	This study received financial support from the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia through the Doctoral Dissertation Research (PDD) Scheme, under Primary

Contract No. 090/E5/PG.02.00.PL/2024 and Secondary Contract No. 0016.025/UN9/SB1.LP2M.PT/2024.

Conflict of Interest : The authors declare no conflict of interest.

Additional Information : Additional information is available for this paper.

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