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Developing a Hypothetical Learning Trajectory for Eighth Graders' Statistical Understanding through Techno-Ethno-Realistic Mathematics Education

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Abstract. Statistics is an important aspect of mathematics that supports the development of students' cognitive abilities. However, understanding statistical concepts often becomes an obstacle for students. This article aims to develop and present a hypothetical learning trajectory on statistics using a techno-ethno-realistic mathematics education (TE-RME) approach. The research was conducted using a design research method that comprises three main stages: preliminary design, design experiments, and retrospective analysis. This research involved eighth-grade students at a junior high school in Semarang. The focus of this article is on the initial design stage, namely the development of a hypothetical learning trajectory that includes three main activities: (1) collecting, presenting, and interpreting data through culturally context-based video observation and spreadsheet, (2) determining the central tendency measures, and (3) determining the measure of data distribution. The series of activities in this learning trajectory is designed to help students build a deeper understanding of statistical concepts while fostering an appreciation of local culture and diversity in mathematical thinking. This hypothetical learning trajectory is designed to be implemented in experimental classes and research-based teaching using TE-RME to improve students' statistical understanding.

Keywords: Design Research; Ethnomathematics; Realistic Mathematics Education; Technology; Statistics

INTRODUCTION

Statistics is recognized as a basic competency for modern citizens, ranging from understanding health information to responding to news and public policy. These skills include the ability to read, evaluate, and critically use data in decision-making (Sánchez et al., 2024). Strong statistical literacy is crucial to be formed at the junior high school level. Strengthening these abilities in the middle class strengthens the foundation of students' data literacy as they become future citizens and workers (Chang et al., 2024). Mastery of statistical literacy at the secondary level contributes to the improvement of students' abilities at higher levels, including high school and university. Therefore, statistics are crucial for students to master.

However, according to some previous research, students still have difficulty learning statistics. Junior high school students are often able to perform simple calculation procedures (e.g., calculating means), but experience conceptual barriers when asked to interpret, choose the right representation, or associate the size of concentration with the size of the spread to make decisions. Recent empirical findings confirm these patterns of difficulty and suggest that the problems are cognitive, representational, and pedagogical (Gok & Goldstone, 2024). Students not only misinterpret graphs but also encounter obstacles when creating informative visualizations (Gok & Goldstone, 2024; Abt et al., 2025) . In addition, students have difficulty assessing average stability or comparing groups to make decisions (Bargagliotti & Eubanks, 2025).

Some of these problems are caused by teachers' inordinate learning design using innovative approaches, contexts, and learning media. Teachers are still dominant in the learning process in the classroom, so students still lack the opportunity to explore their ability to apply the concepts learned. In addition, the lack of opportunities for students to discuss with their peers in solving problems sometimes makes them less able to communicate ideas.

Therefore, it takes teacher intervention to design statistical learning using the right approaches, contexts, and innovative media. One alternative that can be used is to design a Hypothetical Learning Trajectory (HLT) using the integration of E-RME (Prahmana, 2022; Prahmana et al., 2023) and a technology known as Techno-Ethno-Realistic Mathematics

Education (TE-RME) (Nursyahidah et al., 2025a; 2025b). Ethnomathematics connects mathematical concepts with real-life practices and traditions, thereby increasing students' interest, understanding, and creativity (D'Ambrosio, 1999). It focuses on embedding culturally meaningful mathematical ideas into teaching (D'Ambrosio, 2018), and allowing students to engage with content that reflects their own cultural experiences (Kabuye, 2024; Rosa & Orey, 2023).

Similarly, the use of RME in learning design stimulates students to be more actively involved in constructing knowledge (Fajri et al., 2025; Nursyahidah et al., 2020; Nursyahidah and Albab, 2021; Prahmana, 2021). Students also find it easier to understand the concepts learned through the use of relevant contexts (Nursyahidah et al., 2023; Nursyahidah et al., 2023; Hardiyanto et al., 2024; Hartono et al., 2023; Sari et al., 2023) and can generate several models in solving problems [(Nursyahidah et al, 2025; Andzin et al., 2024; Wijaya et al., 2021). Furthermore, integration with technology encourages students to be more enthusiastic and facilitates more inclusive learning (Nursyahidah et al., 2025; Consoli et al., 2025).

One of the key characteristics of Realistic Mathematics Education (RME) is the use of meaningful context in learning. In this study, the context applied to teach statistical material is the *pranata mangsa* system, a Javanese calendar system commonly used by farmers or fishermen. The *pranata mangsa* system was chosen as a learning context to help students engage with the cultural heritage of Central Java and promote more meaningful learning. In this study, it serves as a starting point to explore statistical material, because in the *pranata mangsa* system there is a season division rule accompanied by data on the number of days in each season that can be used as a starting point in learning statistics.

The selected context is presented in the form of a video. In the video, the *pranata mangsa* system is introduced while a series of questions and answers are asked, designed to activate students' previous knowledge in the context of learning. Incorporating multimedia such as video can enhance the learning experience. According to (Er et al., 2022) Interactive videos allow students to build and understand concepts more effectively. Multimedia content, especially videos, supports students with varying abilities in understanding the material (Nursyahidah et al., 2023; Vale & Falloon, 2024) . Therefore, by observing the *pranata mangsa* system through video, students are expected to be able to visualize objects better, serving as a meaningful starting point for learning statistics.

Research that discusses mathematics learning by utilizing RME in statistical materials has been conducted using diverse contexts, such as traditional markets (Sari & Nursyahidah, 2022), and traditional food (Ramadhani et al., 2024), also has not specifically addressed specific mathematical skills. However, the novelty of this study is the use of the context of the *pranata mangsa* system as a starting point in learning using TE-RME, which focuses on problem-solving skills. In addition, this study introduces videos and spreadsheets as a medium to initiate the statistical learning process.

The study uses a design research methodology, which involves three main stages: preliminary design, experimental teaching (including pilot experiments and teaching), and retrospective analysis. However, current research is limited to the early design stages. The goal is to develop HLT on statistical materials for eighth-grade students using the context of a *pranata mangsa* system supported by videos and spreadsheets to strengthen students' problem-solving abilities.

METHODS

This research utilizes design research as a framework for the development of learning theories and educational tools (Bakker, 2018). The subjects of the study were 33 eighth-grade students from public junior high schools in Semarang. Data collection involves a variety of methods, including classroom observations, video recordings, student responses to activity sheets, pre-test and post-test administration, and interviews. The data collected aims to capture the learning process and the thinking process of students. Design research, as outlined by Gravemeijer and Cobb (2026), consists of three main stages: (1) preliminary design, which includes reviewing relevant literature, assessing students' problem-solving skills, formulating Hypothetical Learning Trajectory (HLT), and designing appropriate learning media; (2) Experimental design, which consists of pilot and teaching experiments; and (3) Retrospective analysis, in which all data collected is examined in relation to HLT to refine and improve future instructional designs.

This article focuses only on the results of the first phase, i.e., the preliminary design. This phase involves identifying students' basic abilities, determining their needs in learning statistical material, and constructing HLTs using the cultural context of the *pranata mangsa* system, supported by instructional videos and spreadsheets. The video used in this study is an animation video of the *pranata mangsa* system using Canva, which aims to provide visualization to students about the *pranata mangsa* system, which contains data as a starting point in learning statistics.

RESULTS AND DISCUSSION

Several activities were carried out at the first design research stage, including literature studies, examination of students' initial abilities, and the development of Hypothesis Learning Trajectory. The literature review was conducted by gathering information about statistics from books, followed by a literature review on TE-RME and research design. This is done to develop a preliminary strategy for designing learning. Furthermore, students' talents should be assessed to identify their prerequisites. What is done above is used to create a dynamic hypothesis learning trajectory that can be adjusted during the teaching experiment (Bakker, 2018). In this article, the examination of students' abilities and the formulation of HLT are described as follows.

Examine the basic competencies possessed and needed by students in statistics materials

In studying statistics material for grade VIII junior high school, there are several basic competencies that students already have and competencies that students will acquire. Students already have competencies regarding statistics, such as basic competencies in grade I are: sorting, grouping, comparing, and presenting data using tables and pictograms in at most 4 categories. Furthermore, some basic competencies that have been learned in grades III and IV, including sorting, comparing, presenting, analyzing and interpreting data in the form of tables, picture diagrams, pictograms, and bar charts (scale of one unit). The basic competencies that have been learned in grade V and VI include sorting, comparing, presenting data, and analyzing data from many objects and measurement data in the form of multiple visualizations and in frequency tables to obtain information. Furthermore, the basic competencies that grade VII students already have include: 1) introduction to statistical concepts, types of data, and how to collect, process, and present (in the form of tables and graphs), and 2) analyze simple data.

Furthermore, the basic competencies that grade VIII students will master include: 1) collecting, presenting data, and interpreting data, 2) finding the measure of data centralization, 3) finding the measure of data distribution, and 4) using the measure of centralization and distribution data to solve problems.

Developing a Hypothetical Learning Trajectory

After carrying out literature review activities and reviewing the abilities that students have and need, the next stage is to compile and produce HLT materials to learn statistical material based on the *pranata mangsa* system. This HLT offers a set of learning activity procedures consisting of three activities to help students understand the concepts being learned, inspire students, and provide fun and meaningful learning with the help of animated video media. The three activities can be described as follows.

Activity 1: The purpose of this initial activity is for students to identify data by observing various forms of reference provided, namely through videos, images, and readings about the *pranata mangsa* system. These various forms of learning resources are provided to facilitate the diversity of student learning styles, both audio, visual, and audio-visual. In this phase, students are first asked to watch a video, observe a picture, or review the reading text of *Pranata Mangsa*. After observation, they completed the activity sheet based on what they had seen. This task requires them to collect, present, and interpret data on the number of days in each season contained in the *pranata mangsa* system. Activity sheets are systematically compiled to guide students to achieve the desired learning outcomes. During this process, the teacher's role is to facilitate and encourage students to further explore the cultural context, as well as provide additional insights as needed. Figure 1 illustrates the *pranata mangsa* system that the students investigated during this activity.

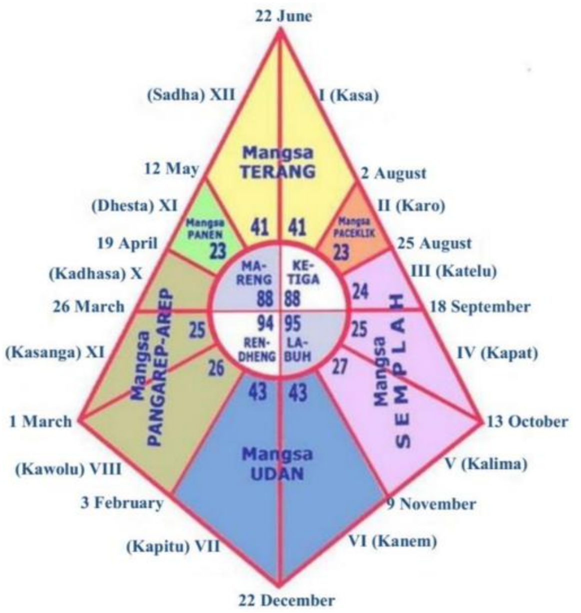

Figure 1. *Pranata mangsa* system as a context

The assumptions of thinking students in activity 1 are shown in Table 1.

Table 1. Students' Thoughts in Activity 1

No	Activity	Conjecture
1	Engage with videos, images, and readings about the *pranata mangsa* system	Students can collect, present, and interpret data
2	Presenting data in a spreadsheet and solving contextual problems related to collecting, presenting, and interpreting data	Students can present data using a spreadsheet and solve problems related to collecting, presenting, and interpreting data

Review of activity 1, in collecting, presenting, and interpreting data, it is expected that students can achieve the learning goals. Some students tend to have difficulties and receive scaffolding assistance from teachers. The teacher's responsibility is to help students find data related to the variety of *pranata mangsa* and the number of days in each season, present it in the form of a table manually or present it on a spreadsheet, and interpret data related to which season is suitable for farmers to plant to get maximum yields.

Activity 2: The learning objectives in Activity 2 are to determine the size of the data center and solve problems related to the size of the data center. Activity 2 begins by observing videos, images, and readings of the context of the *pranata mangsa* system. The purpose of this activity is so that students can find means, medians, mode, and be able to solve contextual problems related to mean, median, and mode.

Students are asked to present data on the number of days in each season on the *pranata mangsa* system, then determine the mean. It is quite easy for students to find the mean using the help of the context of the *pranata mangsa* system, and students will get a wide variety of data based on the type of season that exists. The use of the context of the *pranata mangsa* system will allow students to choose data on the division of seasons in general, as well as more detailed division of seasons.

After the student determines the mean, activity two also directs the student to determine the median. Students are asked to sort the data that has been obtained based on the division of the season and the number of days in each of the seasons. The data is sorted from the smallest to the largest data, then the data located in the middle is searched. Through this activity, students are expected to find the median formula from the data with even or odd numbers. Next, students use the median concepts that have been learned to solve contextual problems. However, if there are still students who have difficulties in this activity, then the role of the teacher is needed as a facilitator, someone who can provide scaffolding so that students can find the median concept appropriately.

The next two activities are for students to find the data that appears most often, namely by sorting the data on the number of days in each season, and finding the data that appears most often to find the mode. Furthermore, students also solve contextual problems related to mode. If students are still having difficulties, the teacher's role is to provide scaffolding so that they can determine the mode and solve the problem appropriately.

Throughout the learning process, teachers provide guidance and ask challenging questions to encourage students' high-level thinking and improve their problem-solving abilities related to mean, median, and mode. This approach aims to foster active participation and a sense of contribution among students. Table 2 also explains the students' thinking in activity 2.

Table 2. Students' Thoughts in Activity 2

No	Activity	Conjecture
1	Engage with videos, images, and readings about the *pranata mangsa* system	Students can specify means, medians, and modes
2	Determine mean, median, and mode using a spreadsheet and solve contextual problems related to mean, median, and mode	Students can determine mean, median, and mode using a spreadsheet and solve contextual problems involving means, medians, and modes

Reflection on activity 2, in determining the mean, median, and mode, as well as solving the problems related to mean, median, and mode, it is hoped that students can achieve the learning goals in activity 2. Some students who are having difficulties will get scaffolding help from teachers. The teacher plays a role in stimulating students to be able to find a variety of possible answers based on the context of the *pranata mangsa* provided to build critical thinking and problem-solving skills with diverse solutions.

Activity 3: The learning objective in activity 3 is to determine the size of the data spread and solve problems related to the size of the data spread. This activity began with students observing videos, observing, drawing, and studying readings related to *pranata mangsa* systems, which displayed various types of division of seasons and the number of days in each season. The use of differentiation of sources is expected to facilitate students who have various learning styles. The goal is to help students make it easier to understand the concepts being studied.

Students were asked to present data on the number of days in each *pranata mangsa* based on the division of seasons presented in the *pranata mangsa* system, then determine the data with the greatest value and the least data and find the difference to determine the range. It's easy enough for students to find ranges using the help of *pranata mangsa* system contexts and students will get a wide variety of data based on the type of season available. The use of the context of the *pranata mangsa* system will allow students to choose data on the division of seasons in general, as well as more detailed division of seasons, so that several possible range results can be obtained depending on the type of division of the season chosen.

After students determine the range, activity three also leads students to determine the quartile. Students are asked to sort the data that has been obtained based on the division of the season and the number of days in each of season. The data is sorted from the smallest to the largest data, then the data located in the middle position is searched to determine the 2nd quartile (Q2). This activity is the same as the previous student activity at the time of determining the median. Furthermore, students were asked to divide the data into two data groups, namely data whose value is less than the median value, and data whose value is more than the median value. Then, students were asked to determine the median in each data group, where the median in group 1 was quartile 1 (Q1) and the median in the second data group was quartile 3 (Q3). Through this activity, students are expected to find quartile formulas.

The next three activities are for students to find the quartile range, i.e. by sorting Q1, Q2, and Q3, and looking for the difference between the largest quartile and the smallest quartile. Next, students look for quartile deviations, namely by dividing the quartile range that has been obtained from previous activities in half. After discovering the range, quartile, quartile range, and quartile deviation, students solve contextual problems related to the concepts of range, quartile, quartile range, and quartile deviation that have been studied. If any students are still having difficulties, the teacher's role is to provide scaffolding so that students can determine the range, quartile, quartile range, and quartile deviation, and solve the problem appropriately.

Throughout the learning process, teachers provide guidance and ask challenging questions to encourage students' high-level thinking and improve their problem-solving abilities related to range, quartile, quartile range, and quartile deviation. This approach aims to foster active participation and a sense of contribution among students. Table 3 explains the students' thinking in activity 3.

Table 3. Students' Thoughts in Activity 3

No	Activity	Conjecture
1	Engage with videos, images, and	Students can specify range, quartile,

	readings about the *pranata mangsa* system	quartile range, and quartile deviation
2	Determine the measure of data distribution using a spreadsheet and solve contextual problems related to range, quartile, quartile range, and quartile deviation	Students can determine the measure of data distribution using a spreadsheet and solve contextual problems involving range, quartile, quartile range, and quartile deviation

Reflection on activity 3, in determining the range, quartile, quartile range, and quartile deviation, as well as solving the problems related to the range, quartile, quartile range, and quartile deviation, it is expected that students can achieve the learning objectives in activity 3. Some students who are having difficulties will get scaffolding help from teachers. The teacher plays a role in stimulating students to be able to find a variety of possible answers based on the context of the *pranata mangsa* provided to build critical thinking and problem-solving skills with diverse solutions.

Based on the findings presented, the initial stage of design research involves preparing for experiments through several key activities. This includes conducting a literature review, analyzing the competencies that students currently possess and the competencies they need to acquire, selecting relevant ethnomathematics-based contexts, formulating Hypothesis Learning Paths, and creating innovative instructional media. These activities serve as the basis for developing an initial instructional strategy. According to (Nursyahidah et al., 2025; Nursyahidah and Albab, 2021), the literature review plays an important role in identifying effective initial strategies for formulating HLTs. This initial design stage is essential to help students progress in understanding statistical concepts from informal ideas to formal mathematical concepts. The use of cultural contexts in TE-RME provides a meaningful starting point and a valuable learning resource for learning these concepts. Previous research supports the idea that learning by involving appropriate context and the help of technology-based media can increase engagement and understanding of concepts (Hardiyanto et al., 2024; Andzin et al., 2024; Nursyahidah et al., 2025), as well as stimulating students' ability to find diverse solutions to given contextual problems (Nursyahidah et al., 2025).

The instructional design is in line with the five core characteristics of RME outlined by (Putri and Zulkardi, 2018) 1) The use of context: this study utilizes the ethnomathematical context of the *pranata mangsa* system. 2) The use of models, instructional models, helps guide students from informal understanding to formal mathematical concepts. 3) Student contribution, each activity encourages student input and participation as a path to achieve learning goals. 4) Interactivity, learning involves interaction through discussion, explanation, feedback, collaboration, and evaluation. 5) Intertwinement, activities integrating related mathematical concepts such as mean, median, mode, range, quartile, quartile range, and quartile deviation, and cultural traditions to promote holistic understanding.

Using ethnomathematics as a learning context can stimulate students' understanding and problem-solving skills (Nursyahidah and Albab, 2021; Nursyahidah et al., 2023). Each learning activity is designed so that students can use the concepts learned to solve real-life problems involving mean, median, mode, range, quartile, quartile range, and quartile deviation, reinforcing the relevance and significance of RME. Students are encouraged to actively participate and apply what they learn in a practical context. Studies by (Nursyahidah et al., 2023; Putri and Zulkardi, 2018) and (Silva, 2022) confirm that RME improves the learning experience, while (Silva et al., 2022) highlight its success in improving math achievement. Furthermore, the use of technology in the form of animated videos can help with visualization and make it easier for students to learn abstract mathematical concepts (Nursyahidah et al., 2025).

Finally, using TE-RME provides a comprehensive method for teaching statistics material. This practice enhances students' conceptual knowledge by blending realistic cultural and event backgrounds. It also improves engagement, concept understanding, and problem-solving abilities. These results are supported by previous studies, which highlight the effectiveness of TE-RME as a forward-thinking and impactful teaching strategy.

CONCLUSION

This research has succeeded in developing HLT for the learning of statistical materials through TE-RME using a *pranata mangsa* system as a cultural context to support students' problem-solving skills. HLTs created during the initial design phase can be implemented in the next phase, i.e., the experimental design phase. The HLT includes three main activities: observing video, images, and reading of the *pranata mangsa* system to collect, present, interpret data, and resolve related contextual problems; determine the size of data centralization and resolve related contextual issues; determine the size of the data dissemination and resolve related contextual issues. This sequential activity is structured to guide students in developing conceptual understanding and improving problem-solving skills. These findings underscore the potential of combining local cultural knowledge through ethnomathematics with the RME framework based on technological media to improve conceptual understanding and problem-solving skills in statistical learning.

Despite these promising results, the study has some limitations. First, this research focuses on the context of a certain culture, namely the *pranata mangsa* system, which may not be directly applicable to students from different regions or cultures. Second, this study only examines understanding and problem-solving in the context of statistical material and does not explore other learning dimensions. In addition, the limited duration of the intervention and the relatively small sample size may affect the wider application and long-term impact of the findings. Overcoming these limitations in future research could provide a deeper and more comprehensive evaluation of the approach.

Future studies are encouraged to build on this research by implementing HLTs developed in a broader context. In order to develop a varied learning trajectory that takes into account a wide range of cultural and geographical backgrounds, it is necessary to investigate the integration of additional ethnomathematical contexts and to broaden the range of application of the TE-RME approach to include other mathematical materials and abilities. Through these efforts, researchers and educators can continue to advance mathematics education using culturally meaningful and technology-integrated instructional strategies by paying attention to the characteristics of students and the mathematics materials studied.

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