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# Designing a Learning Trajectory for Mode Using a PMRI-STEM Approach in a Coffee Grinder Context for Culinary Arts Vocational High School Students

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## Abstract

Mode is one of the measures of central tendency that students often learn procedurally by identifying the most frequently occurring value, without understanding its meaning in real-world situations. This study aimed to design a learning trajectory for mode using a PMRI-STEM approach and a coffee grinder context to support students' conceptual understanding and contextual reasoning in vocational mathematics. The study employed a design research approach consisting of preliminary design, teaching experiment, and retrospective analysis. The participants were 25 Grade 10 students in a Culinary Arts Vocational High School. Data were collected through classroom observations, student worksheets, interviews, and learning documentation and were analyzed descriptively to examine students' learning processes and strategies. The resulting learning trajectory involved activities in adjusting coffee grinder settings, grinding coffee beans at different grind sizes, observing brewing characteristics, organizing preference data into frequency tables, and identifying the mode as the most frequently selected grind size. The findings showed that students were able to determine the mode and interpret it as an indicator of majority customer preference for determining standard coffee shop menu settings. Students also connected grinder settings, brewing results, data representation, and statistical decision-making through contextual reasoning. These findings suggest that a PMRI-STEM approach using a coffee grinder context can support students' understanding of mode and develop contextual statistical literacy in vocational mathematics learning.

**Keywords:** Coffee Grinder; Culinary Arts Vocational High School; Mathematical Literacy; Mode Learning; PMRI-STEM Approach

## Introduction

Mathematical literacy is an important ability that enables students to understand, use, interpret, and evaluate mathematics in real-life situations. From the PISA perspective, mathematical literacy involves formulating situations mathematically, applying mathematical concepts and procedures, and interpreting mathematical results in meaningful contexts (OECD, 2023; Stacey, 2011; 2014). Thus, mathematical literacy goes beyond procedural calculation and includes reasoning, representing information, interpreting data, and using mathematics to support decision-making (Genc & Erbas, 2019; Risdiyanti et al., 2024; Serin, 2023). However, students in Indonesia continue to experience difficulties in connecting mathematical ideas with contextual situations and interpreting mathematical information in real-life problems (Putri & Zulkardi, 2020; Wijaya et al., 2024; Zulkardi & Kohar, 2018).

These challenges are particularly relevant in vocational education, where mathematics is expected to support students' practical and occupational needs. In vocational high schools, students need mathematics not only to solve school-based problems but also to analyze information, interpret data, and make decisions related to their fields of expertise. Mathematics learning should therefore provide opportunities for students to experience how mathematical concepts are used in authentic activities and workplace-related situations (OECD, 2023; Risdiyanti et al., 2024; Stacey, 2014). Statistics is particularly relevant in this regard because students can use data to describe situations, identify patterns, and support decisions related to practical activities (Dierdorp et al., 2014; Fisher et al., 2020).

One statistical concept that can be connected to vocational activities is mode, a measure of central tendency that identifies the value or category with the highest frequency in a data set. Understanding mode is important because it can help students summarize and interpret categorical or numerical data in context (Cazorla et al., 2023; Parra-Fica et al., 2024). However, students often learn mode procedurally by identifying the value that occurs most frequently, without considering what the mode represents in a particular situation (Koparan, 2015; Landtblom, 2023). As a result, students may obtain the correct answer from a frequency table but have difficulty explaining why the mode is meaningful or how it can be used to support a decision (Ismail & Chan, 2015; Saidi & Siew, 2018). Learning mode therefore needs to move beyond identifying the highest frequency toward interpreting that frequency within a meaningful context.

A relevant context for this purpose is coffee preparation in Culinary Arts education. The use of a coffee grinder involves selecting and adjusting grind sizes, such as coarse, medium, and fine, according to the intended brewing process. Students can collect and organize data on preferred grind sizes and determine which category occurs most frequently. In such a situation, the mode can be interpreted as the most frequently selected grind size and used as information for making practical decisions about coffee preparation. A coffee grinder therefore provides a familiar vocational context in which students can connect statistical data with tools, processes, observations, and decision-making.

Context-based mathematics learning can support students in developing mathematical understanding from meaningful situations. Realistic Mathematics Education (RME) emphasizes the use of meaningful contexts as starting points from which students progressively develop formal mathematical ideas (Revina & Leung, 2019; Zulkardi et al., 2020). In Indonesia, this approach is known as *Pendidikan Matematika Realistik Indonesia* (PMRI). PMRI encourages students to explore contextual situations, develop informal strategies, construct mathematical models, discuss solutions, and gradually move toward more formal mathematical representations (Fauzan et al., 2018; Putri & Zulkardi, 2020; Zulkardi & Putri, 2019). The development of a learning trajectory is important in this process because it describes how students' thinking and informal strategies can develop through a sequence of carefully designed learning activities (Armiati et al., 2022; Gravemeijer & Cobb, 2013; Rawani et al., 2023).

The PMRI approach can be further strengthened by integrating STEM principles. STEM-based learning connects science, technology, engineering, and mathematics through practical problem-solving activities and the use of tools and technologies relevant to real situations (Dierdorp et al., 2014; Geitz & de Geus, 2019). In the context of Culinary Arts, the integration of PMRI and STEM can provide opportunities for students to work with actual equipment, observe processes and outcomes, collect and represent data, and use mathematical reasoning to make decisions. Such integration is particularly relevant to vocational mathematics because it connects mathematical concepts with the practical activities and technologies that students may encounter in their future workplaces.

Previous studies have demonstrated the potential of realistic contexts and PMRI for supporting students' understanding of statistics. Fauzan et al. (2018), for example, developed a learning trajectory for statistics using an RME approach, while Meitrilova and Putri (2020) developed PMRI-based learning activities for central tendency. Rahayu and Putri (2021) showed that PMRI-based learning could help students connect contextual data with formal understanding of the mean. Other studies have used contextual tasks to develop students' mathematical literacy by engaging them in interpreting and solving real-world problems (Putri & Zulkardi, 2020; Zulkardi & Kohar, 2018; Zulkardi et al., 2020). Recent research has also highlighted the importance of learning environments that connect mathematical tasks, meaningful contexts, teacher support, and students' learning processes (Gustiningsi et al., 2023; Risdiyanti et al., 2024).

Despite these developments, limited research has examined the design of learning trajectories for mode using a vocational context and an integrated PMRI-STEM approach. Existing studies have more commonly addressed statistics in general or focused on other measures of central tendency, particularly the mean. In addition, the use of authentic equipment and processes from Culinary Arts education as a context for learning mode has received limited attention. This creates an opportunity to develop learning activities in which students do not merely determine the mode from a prepared data set but generate, organize, interpret, and use data arising from a vocational activity. Such a learning trajectory may provide a meaningful connection between statistical concepts, mathematical literacy, and students' vocational experiences.

Based on this gap, this study aimed to design a learning trajectory for teaching mode using a PMRI-STEM approach in the context of coffee grinder use for Grade 10 students in a Culinary

Arts Vocational High School. The learning trajectory was designed around activities involving grinder settings, coffee grinding, observation of brewing characteristics, collection and organization of grind-size preference data, and interpretation of the most frequently selected category. The study focused on how these activities supported students in developing an understanding of mode and connecting statistical information with practical decision-making. Specifically, the study addressed the following research question:

> *How does a PMRI-STEM learning trajectory using a coffee grinder context support Grade 10 Culinary Arts students in understanding and applying the concept of mode?*

## Methods

This study employed a design research approach using a validation study to design, implement, and investigate a learning trajectory for teaching mode through a PMRI-STEM approach using the context of a coffee grinder in a Culinary Arts Vocational High School. Design research was selected because it enables researchers to develop and refine instructional designs through iterative cycles of design, implementation, analysis, and revision, with particular attention to how students' mathematical understanding develops during learning activities (Bakker, 2018; Gravemeijer & Cobb, 2006). The study was theoretically grounded in a constructivist perspective, which views mathematical understanding as being constructed through meaningful activities and interactions between students and contextual situations. Accordingly, the design research approach was appropriate for investigating how PMRI-STEM activities could support students in developing an understanding of mode through a vocationally relevant context.

### Research Participants

The participants were 25 tenth-grade students enrolled in the Culinary Arts program at a Vocational High School. Participants were selected purposively because the learning context was directly related to their vocational field. The coffee grinder was selected as the learning context because its use is relevant to practical activities in culinary arts and coffee preparation, providing opportunities for students to connect statistical concepts with experiences related to their field of study. Such vocationally relevant contexts can provide meaningful situations in which students apply mathematical ideas to practical activities and workplace-related decision-making.

### Research Procedure

The research procedure followed three main stages of design research: preliminary design, teaching experiment, and retrospective analysis (Gravemeijer & Cobb, 2006; Bakker, 2018), as illustrated in Figure 1.

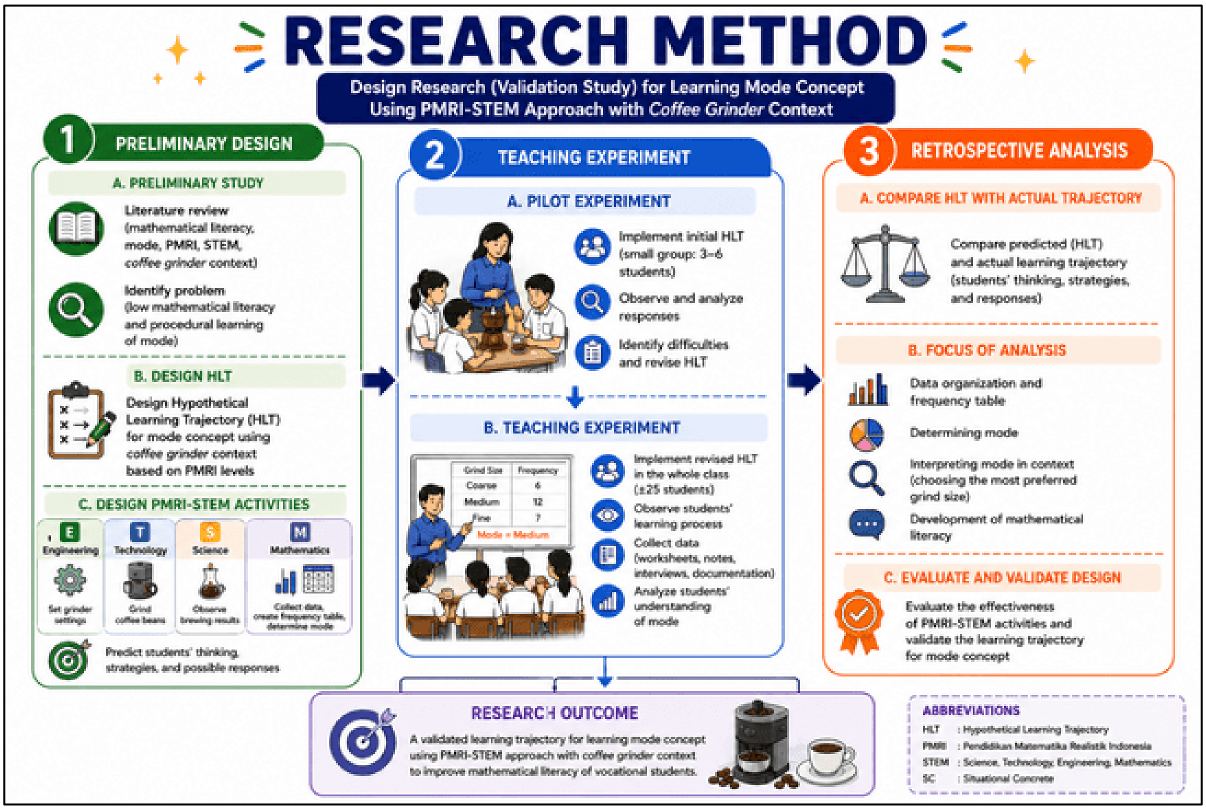



**Figure 1.** Research procedure

During the preliminary design stage, the researchers reviewed literature related to mathematical literacy, the concept of mode, PMRI, STEM education, coffee-grinder use, and mathematics learning in Culinary Arts Vocational High Schools. The literature review informed the development of a Hypothetical Learning Trajectory (HLT) consisting of learning objectives, a sequence of learning activities, and predicted student strategies and responses. The HLT was designed based on the PMRI principle of emergent modelling, progressing from students' situational understanding toward increasingly formal mathematical reasoning through the levels of model of, model for, and formal mathematical knowledge. To facilitate this progression, the learning activities integrated relevant STEM elements within a vocational context. Students began by exploring how a coffee grinder can be adjusted to produce different grind sizes. They then used the grinder to process coffee beans with different settings and observed differences in the resulting coffee brews. These activities provided a contextual basis for collecting and organizing data on grind-size preferences. Students subsequently represented the data in frequency tables and determined the mode as the category occurring most frequently.

Furthermore, the teaching experiment consisted of a pilot experiment followed by the main teaching experiment. The pilot experiment was conducted with a small group of students to identify potential learning obstacles, examine the feasibility of the learning activities, and evaluate the alignment between the HLT and students' actual responses. Findings from the pilot experiment were used to revise the HLT and instructional activities before implementation in the main teaching experiment. The main teaching experiment was conducted with the 25 participating students. During the learning activities, the researchers observed students' strategies, interactions, representations, and developing understanding of mode. Particular attention was given to how students progressed from the contextual situation of coffee-grinder use to the organization and interpretation of categorical data. The researchers also examined how students used frequency information to identify the mode and interpret it as an indicator of the majority preference in a coffee-shop context.

Finally, the retrospective analysis compared the Hypothetical Learning Trajectory with the students' actual learning trajectory during the teaching experiment. The analysis examined similarities and differences between the predicted learning processes and students' observed strategies, responses, and emerging understanding (Gravemeijer & Cobb, 2006). Particular attention was given to how students developed an understanding of mode from the contextual situation, how they organized and represented preference data, and how the PMRI-STEM activities supported the transition from contextual reasoning to formal statistical understanding. The results of the retrospective analysis were used to refine the learning trajectory and identify the characteristics of instructional activities that supported students' understanding of mode in the vocational context.

## Data Collection and Analysis

Data were collected through classroom observations, student worksheets, semi-structured interviews, learning documentation, and students' written work produced during the learning activities. The data focused on students' strategies for organizing categorical data, determining frequencies, identifying the mode, and interpreting the mode in the context of decision-making related to coffee-shop practices.

The collected data were analyzed descriptively and qualitatively to trace the development of students' understanding throughout the learning trajectory. Students' written work and worksheets were analyzed to identify their representations, calculations, and interpretations of frequency and mode. Classroom observations and learning documentation were used to examine students' interactions, strategies, and responses during the activities, while interviews were used to clarify students' reasoning and interpretations. The different sources of evidence were then compared to identify patterns in students' learning processes and to determine how the observed learning trajectory corresponded with the HLT.

The credibility of the findings was supported through triangulation of data sources and collection methods by comparing classroom observations, students' written responses, interview data, and learning documentation (Bakker, 2018; Gravemeijer & Cobb, 2006). In addition, the learning trajectory was iteratively refined based on evidence obtained during the pilot experiment and main teaching experiment. This iterative process helped ensure that the instructional activities were responsive to students' actual learning processes and classroom conditions.

## Ethical Considerations

Prior to data collection, permission was obtained from the participating school and the research participants. The participants were informed about the purpose and procedures of the study and provided consent for their participation, the use of classroom documentation, and the collection of photographs and other learning-related documentation. All data were used solely for academic purposes, and participants' identities were kept confidential throughout the research process.

## Results and Discussion

This study resulted in a learning trajectory for developing students' understanding of mode through a PMRI-STEM approach using the context of coffee-grinder use in Culinary Arts Vocational High School. The learning activities integrated Engineering, Technology, Science, and Mathematics through a sequence of contextual and vocationally relevant experiences. The sequence began with students adjusting a coffee grinder to produce different grind sizes as part of the engineering activity. Students then operated the grinder to produce coffee grounds according to the selected settings in the technology activity.

Next, students observed and compared the characteristics of coffee brewed from different grind sizes as part of the science activity. In the mathematics activity, students collected data on grind-size preferences, organised the responses into a frequency table, and identified the mode as the most frequently selected grind-size category. The learning trajectory was also structured according to the PMRI levels of thinking: situational, model-of, model-for, and formal knowledge. Through this sequence, students were expected to develop an understanding of mode beyond simply identifying the category with the highest frequency. They were also encouraged to interpret the mode as an indicator of the most common preference in the dataset and to use this information to support contextual decision-making.

### Hypothetical Learning Trajectory of Mode Learning Using the Coffee Grinder Context

The HLT was developed to guide the learning of mode through a coffee-grinder context relevant to students in the Culinary Arts Vocational High School presented in Table 1. Following the HLT framework, the trajectory comprised learning objectives, a sequence of learning activities, and predictions of students' strategies and responses during the learning process. The design was intended to support students in progressing from concrete experiences with coffee preparation toward increasingly formal representations of categorical data and the concept of mode.

The learning trajectory integrated the PMRI levels of thinking with the STEM components of engineering, technology, science, and mathematics. Students initially engaged with the coffee grinder by adjusting its settings and producing different grind sizes. They subsequently examined the resulting coffee grounds and brewed coffee to identify differences in texture and taste. These experiences provided a contextual basis for collecting and organizing preference data. In the final activity, students represented the data in a frequency table, identified the category with the highest frequency, and interpreted it as the mode. Thus, mode was introduced not as an isolated statistical procedure, but as a mathematical tool for interpreting preferences and supporting decisions in a vocational context.

**Table 1.** HLT of Mode Learning using Coffee Grinder Context

| Learning activities | STEM component | Students' constructed understanding | Predicted students' responses | Predicted teacher responses |
|---|---|---|---|---|
| Activity 1 – Engineering: Adjusting Coffee Grinder Settings | Engineering | Students recognize that grinder settings determine the size of coffee grounds and that different settings produce different grind sizes, ranging from extra fine to extra coarse. | Students identify the grinder components used to adjust the grind size, experiment with several settings, and record the relationship between the settings and the resulting grind sizes. Some students may initially assume that different settings produce similar results but revise their understanding after direct observation. | The teacher guides students to identify the relevant grinder components and operate the equipment safely. Guiding questions include: "What happens when the grinder setting is changed?" and "Which setting produces finer or coarser grounds?" |
| Activity 2 – Technology: Grinding Coffee Beans Using a Grinder | Technology | Students recognize that a coffee grinder functions as a technological tool for producing coffee grounds with different particle sizes according to selected settings. | Students operate the grinder, produce samples using different settings, label the samples, and compare the resulting particle sizes. They describe the samples using categories such as very fine, fine, medium, coarse, and very coarse. | The teacher supports students in following the grinding procedure systematically, labeling samples, comparing results, and operating the equipment appropriately and safely. |
| Activity 3 – Science: Observing Differences in Coffee Grind and Brewing Results | Science | Students recognize that grind size is associated with observable differences in particle texture and may influence the characteristics of the brewed coffee. | Students compare particle size, texture, and sensory characteristics across samples and record their observations. They may describe finer grounds as producing stronger or more bitter coffee and coarser grounds as producing lighter-tasting coffee. | The teacher encourages systematic observation and comparison and prompts students to explain relationships between grind size and brewing characteristics through questions such as: "How does the texture of fine grounds differ from that of coarse grounds?" and "How might grind size affect the brewed coffee?" |
| Activity 4 – Mathematics: Determining | Mathematics | Students understand that categorical | Students collect preference data, classify responses according to | The teacher guides students in organizing the data, comparing |

| Learning activities | STEM component | Students' constructed understanding | Predicted students' responses | Predicted teacher responses |
|---|---|---|---|---|
| the Most Preferred Grind Size Using Mode | | preference data can be organized according to frequency and that the category with the highest frequency represents the mode and can inform a decision. | grind size, construct a frequency table, identify the category with the highest frequency, and interpret it as the most preferred grind size. They use the result to propose a menu or preparation recommendation. | frequencies, identifying the highest frequency, and connecting this result to the formal definition of mode. Students are prompted to justify whether the identified mode provides a reasonable basis for a recommendation. |

Table 1 shows how the HLT was designed to facilitate a gradual transition from students' direct experiences to formal statistical reasoning. In the initial activities, students interacted directly with the coffee grinder and observed variations in grind size. These experiences established the situational context from which students could recognize that coffee grounds can be distinguished and categorized. The subsequent observation of grinding and brewing characteristics provided additional contextual information before students engaged in explicit data analysis.

The transition toward statistical reasoning occurred when students collected and organized preference data. Rather than receiving a preconstructed data set, students generated categorical data from a meaningful vocational situation and represented the responses in a frequency table. This representation was intended to function as a model of the contextual situation by making the distribution of preferences visible. Students were then expected to use the frequency table as a model for comparing categories, identifying the highest frequency, and interpreting the mode as an indicator of the majority preference. Through this progression, the HLT connected the PMRI levels of situational context, model of, model for, and formal knowledge.

## Activity 1 – Engineering: Adjusting Coffee Grinder Settings

The first activity focused on adjusting the coffee grinder to produce different grind sizes. Students experimented with several grinder settings, including coarse, medium, and fine, and observed the resulting differences in coffee-ground texture. The activity provided a concrete starting point for students to explore the relationship between the grinder setting and the characteristics of the resulting coffee grounds as shown in Figure 2.

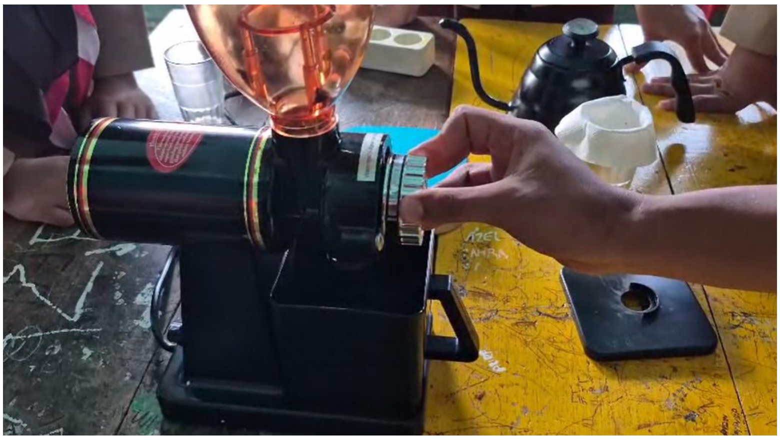


**Figure 2.** Students Adjusting Coffee Grinder Settings

During the activity, students actively experimented with different grinder settings and discussed the resulting coffee grounds. Most students recognized that changing the grinder setting produced observable differences in particle size and texture. They described the coarse setting as producing larger and rougher particles, the medium setting as producing intermediate-sized particles, and the fine setting as producing smaller and smoother particles. These observations indicated that students were able to identify a relationship between the adjustment of the tool and the resulting grind size through direct manipulation and observation.

Some students also began to relate grind size to the characteristics of brewed coffee. They noted that different grind sizes could influence the resulting flavor, thereby connecting the physical characteristics of the coffee grounds with their subsequent use in coffee preparation. Although this connection was not yet expressed in formal mathematical terms, it provided an initial basis for relating the practical activity to coffee preparation practices in the vocational context.

From a PMRI perspective, students remained primarily at the situational level during this activity. Their understanding was grounded in direct interaction with the coffee grinder, experimentation with different settings, and observation of the resulting coffee grounds. The activity therefore established the contextual foundation for subsequent mathematical activities by generating observable variations in grind size that could later be categorized, recorded, and analyzed.

### Activity 2 – Technology: Grinding Coffee Beans Using a Coffee Grinder

The second activity focused on using the coffee grinder as a technological tool to produce coffee grounds according to predetermined settings as shown in Figure 3. Building on the previous activity, students prepared the coffee beans, selected the grinder settings, operated the grinder, and placed the resulting grounds into labeled sample containers. The activity was intended to help students recognize how a technological tool can be used systematically to produce and compare different grind sizes.

**Figure 3.** Students Grinding Coffee Beans Using a Coffee Grinder

Students produced coffee-ground samples using several grinder settings, including extra fine, fine, medium fine, medium, medium coarse, coarse, and extra coarse. They then compared the resulting samples and recorded their observations regarding particle size and texture. Students used descriptive categories such as very fine, fine, medium, coarse, and very coarse to distinguish the characteristics of the samples.

The activity revealed that students increasingly recognized the relationship between grinder settings and particle size. They observed that finer settings generally produced smaller and smoother particles, whereas coarser settings produced larger and rougher particles. These observations enabled students to move beyond simply operating the grinder toward identifying and describing systematic differences in the resulting coffee grounds.

Importantly, students began to organize their observations in a structured form by recording the grinder setting, grind-size category, and observed characteristics in a table. This representation transformed their direct experience with the grinder into organized information that could be compared across samples. The table therefore served as an initial model of the situation, representing observable relationships between grinder settings and grind-size characteristics.

From the PMRI perspective, this activity marked a transition from the situational level toward the model-of level. Students were no longer relying solely on direct sensory experience; they began to represent aspects of the situation through categories and organized observations. This representation provided a basis for the subsequent activity, in which students examined coffee characteristics and eventually generated preference data for statistical analysis.

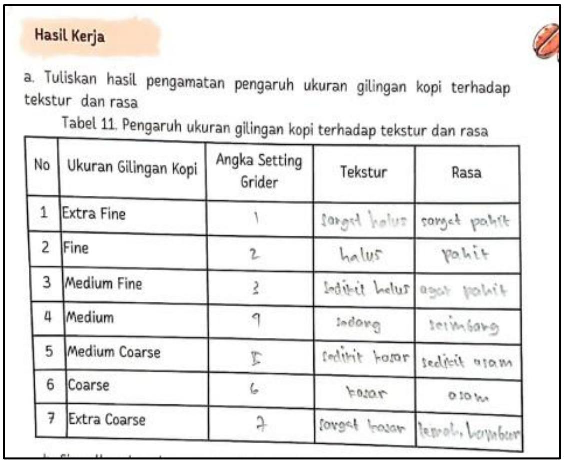
## Activity 3 – Science: Observing the Effects of Grind Size on Coffee Characteristics

The third activity constituted the science phase and focused on examining how different grind sizes were associated with observable characteristics of brewed coffee illustrated in Figure 4. After producing coffee grounds using different grinder settings, students brewed the samples and compared their particle characteristics, texture, and taste. The activity provided an opportunity for students to connect the physical properties of the coffee grounds with observable outcomes in the brewing process.

**Figure 4.** Students Brewing Coffee Using Different Grind Sizes

During the activity, students compared coffee samples ranging from extra fine to extra coarse. They observed noticeable differences in texture and taste across the samples. The extra-fine grind was described as having a very smooth texture and producing a relatively bitter taste, whereas the fine and medium-fine grinds were also perceived as relatively smooth and bitter. The medium grind was described as having an intermediate texture and a more balanced taste. In contrast, the medium-coarse, coarse, and extra-coarse grinds were characterized by progressively rougher textures and lighter or weaker tastes.

Students subsequently discussed possible relationships between grind size and the sensory characteristics of the brewed coffee. They generally associated finer grounds with stronger and more bitter flavors and coarser grounds with lighter or weaker flavors. These observations enabled students to move beyond identifying differences in particle size toward explaining how variations in the grinding process could be associated with differences in the resulting coffee as shown in Figure 5.



Hasil Kerja

a. Tuliskan hasil pengamatan pengaruh ukuran gilingan kopi terhadap tekstur dan rasa

Tabel 11. Pengaruh ukuran gilingan kopi terhadap tekstur dan rasa

| No | Ukuran Gilingan Kopi | Angka Setting Grider | Tekstur | Rasa |
|---|---|---|---|---|
| 1 | Extra Fine | 1 | sangat halus | sangat pahit |
| 2 | Fine | 2 | halus | pahit |
| 3 | Medium Fine | 3 | sedikit halus | agak pahit |
| 4 | Medium | 4 | sedang | seimbang |
| 5 | Medium Coarse | 5 | sedikit kasar | sedikit asam |
| 6 | Coarse | 6 | kasar | asam |
| 7 | Extra Coarse | 7 | sangat kasar | terlalu, hambar |

**Results**

a. Write down the observation results on the effect of coffe grind size on texture and taste

Table 1. The effect of Coffee Grind Size on Texture and Taste

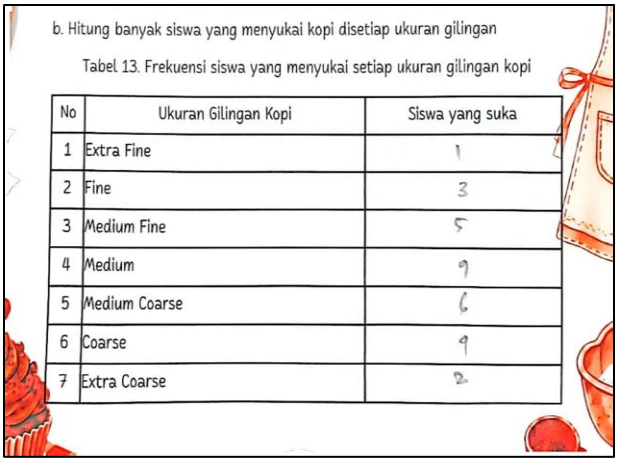
| No | Coffee Grind Size | Grinder Setting Number | Texture | Taste |
|---|---|---|---|---|
| 1 | Extra Fine | 1 | Very fine | Very Bitter |
| 2 | Fine | 2 | Fine | Bitter |
| 3 | Medium Fine | 3 | Slightly Fine | Slightly Bitter |
| 4 | Medium | 4 | Medium | Balanced |
| 5 | Medium Coarse | 5 | Slightly Coarse | Slightly Sour |
| 6 | Coarse | 6 | Coarse | Sour |
| 7 | Extra Coarse | 7 | Very Coarse | Too Sour / Watery |

**Figure 5.** Students Observing the Effect of Coffee Grind Size on Texture and Taste

The students recorded their observations in a structured table, linking grind-size categories with the observed characteristics of the coffee. This representation helped transform their direct sensory experiences into organized information that could be compared across categories. From the PMRI perspective, the activity therefore strengthened the transition toward the model-of level, as students used a tabular representation to describe and compare aspects of the contextual situation. Importantly, the table did not yet function as a statistical model for decision-making; rather, it provided an organized representation of the coffee-brewing situation that prepared students for the subsequent analysis of preference data.

## Activity 4 – Mathematics: Determining the Most Preferred Coffee Grind Size Using Mode

The fourth activity focused on formalizing the concept of mode through students' preferences for different coffee grind sizes. Building on their previous experiences with grind-size categories and coffee characteristics, students collected preference data, classified the responses according to grind size, and represented the data in a frequency table. The purpose of this activity was to support students in recognizing that categorical data can be summarized by frequency and that the category with the highest frequency can be identified as the mode as shown in Figure 6.



b. Hitung banyak siswa yang menyukai kopi disetiap ukuran gilingan

Tabel 13. Frekuensi siswa yang menyukai setiap ukuran gilingan kopi

| No | Ukuran Gilingan Kopi | Siswa yang suka |
|---|---|---|
| 1 | Extra Fine | 1 |
| 2 | Fine | 3 |
| 3 | Medium Fine | 5 |
| 4 | Medium | 9 |
| 5 | Medium Coarse | 6 |
| 6 | Coarse | 9 |
| 7 | Extra Coarse | 2 |

b. Calculate the number of students who prefer coffee at each grind size.

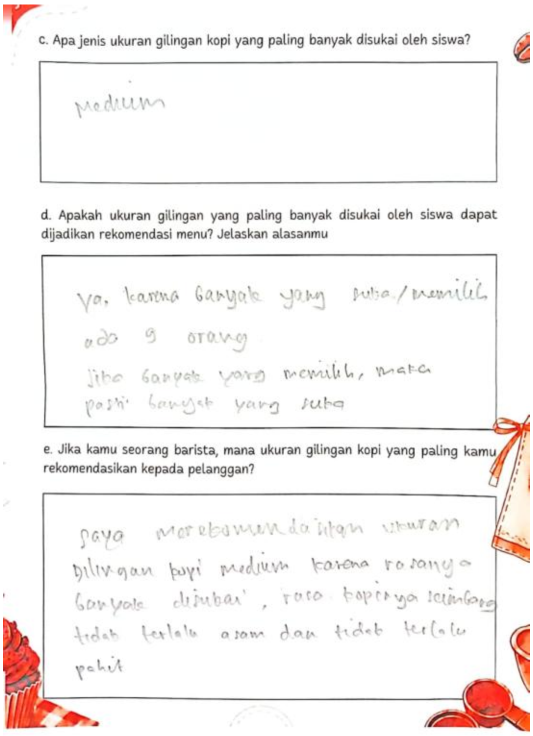
Table 13. Frequency of Students Who Prefer Each Coffee Grind Size

| No | Coffe Grind Size | Number of Students Who Prefer It |
|---|---|---|
| 1 | Extra Fine | 1 |
| 2 | Fine | 3 |
| 3 | Medium Fine | 5 |
| 4 | Medium | 9 |
| 5 | Medium Coarse | 6 |
| 6 | Coarse | 9 |
| 7 | Extra Coarse | 2 |

**Figure 6.** Students' Frequency Tables of Grind-Size Preferences

The students successfully organized the preference data into a frequency table. The recorded frequencies were 1 student for extra fine, 3 for fine, 5 for medium fine, 9 for medium, 6 for medium coarse, 4 for coarse, and 2 for extra coarse. By comparing these frequencies, students identified medium as the category with the highest frequency.

The frequency table helped students move from individual responses to an aggregate representation of the group's preferences. Rather than considering each student's choice separately, students could compare the frequencies across categories and identify the dominant pattern in the data as shown in Figure 7. This process supported the construction of the meaning of mode as the category that occurs most frequently in a categorical data set.




c. Which coffee grind size is liked by the greatest number of students?

Medium

d. Can the grind size that is liked by the greatest number of students be recommended as a menu option? Explain your reason.

Yes, because 9 people chose it. If many people choose it, it means that many people like it.

e. If you were a barista, which coffee grind size would you recommend to customers?

I recommend a medium coffee grind size because it is preferred by many people. The coffee has a balanced taste, as it is neither too sour nor too bitter.

**Figure 7.** Students Determining the Mode from Frequency Tables

Students were then asked to interpret the statistical result in the context of a coffee shop. Most students explained that the medium grind size could be recommended because it was selected by the largest number of respondents. One student further justified the recommendation by referring to the perceived taste of medium-ground coffee as balanced, neither too sour nor too bitter. Thus, students connected the statistical result with their previous sensory observations and used the mode as a basis for making a contextual recommendation.

## From Model-of to Model-for: Constructing the Meaning of Mode

The mathematics activity marked an important transition from the model-of to the model-for level within the PMRI framework. Initially, the frequency table served as a representation of students' contextual preference data. As students compared the frequencies across grind-size categories, however, the table gradually became a mathematical tool for identifying the category with the highest frequency and using this information to make a contextual decision. Students subsequently formalized this reasoning by identifying the most frequently selected category as the mode. Thus, the activity connected students' contextual experiences with data representation, statistical reasoning, and practical decision-making within a coherent learning sequence.

This development is important because students did not merely identify the category with the highest frequency; they interpreted what that category meant in the coffee-shop context. Students recognized that the medium grind size, which was selected most frequently, could be considered a recommendation because it represented the dominant preference among the respondents. The mode was therefore constructed not simply as a statistical answer, but as information that could support a practical decision. This progression illustrates how contextual models can evolve into mathematical tools for reasoning, consistent with the PMRI principle of progressive mathematization (Zulkardi & Putri, 2019; Zulkardi et al., 2020; Fauzan et al., 2018).

The findings further indicate that the PMRI-STEM learning trajectory provided a coherent pathway from vocational experience to formal statistical reasoning. Rather than introducing mode through a definition or a predetermined frequency table, the learning began with students' direct engagement with a coffee grinder and gradually transformed their experiences into observable data, categorical representations, and statistical conclusions. This progression is consistent with the broader conception of mathematical literacy, in which students are expected not only to perform mathematical procedures but also to formulate, represent, interpret, and use mathematical information in meaningful situations (Stacey, 2011, 2014; OECD, 2023; Risdiyanti et al., 2024).

## Integration of Engineering and Technology in the Learning Trajectory

The engineering activity provided the initial experiential foundation for the learning trajectory. By adjusting the grinder settings and observing differences in the resulting coffee grounds, students encountered a concrete situation in which variations in a technical setting produced observable variations in output. This experience created an authentic need to distinguish and classify different grind sizes before the mathematical concept was introduced. Such an approach is consistent with PMRI, in which meaningful real-world situations serve as starting points from which students progressively develop more formal mathematical representations (Zulkardi & Putri, 2019; Zulkardi et al., 2020; Fauzan et al., 2018).

The engineering activity also contributed to the STEM dimension of the learning design because students interacted directly with a technological artefact and considered how its settings influenced the resulting product. Rather than treating the grinder merely as an instructional prop, the activity positioned it as part of the problem situation from which relevant observations and data could be generated. This is consistent with STEM-oriented learning that connects mathematical reasoning with the use of tools, practical processes, and observable phenomena (Dierdorp et al., 2014; Fisher et al., 2020). Consequently, students began to recognize that quantitative and categorical information can originate from practical activities rather than being provided independently of the situation.

The subsequent technology activity strengthened this connection by requiring students to operate the grinder systematically, produce samples at different settings, and document the resulting grind characteristics. The resulting records transformed students' direct experiences into organized information. This represented an initial movement from the situational level toward the model-of level in PMRI because students began to use tables and categorical descriptions to represent aspects of the grinding process. Such contextual data organization is particularly relevant to statistics learning because it allows students to experience how data are generated, classified, and prepared for subsequent analysis (Meitrilova & Putri, 2020; Rahayu & Putri, 2021).

## Scientific Observation as a Bridge to Mathematical Representation

The science activity extended students' observations from the physical characteristics of coffee grounds to the characteristics of the resulting brew. Students compared grind sizes and described differences in texture and taste, recognizing that finer grounds tended to produce stronger or more bitter flavours, whereas coarser grounds tended to produce lighter flavours. These observations enabled students to connect the technical characteristics of the grinding process with an observable outcome in coffee preparation.

From a learning perspective, this activity provided an additional layer of meaning to the data subsequently used in the mathematics activity. Students were not working with arbitrary categories; the categories had been encountered through a sequence of authentic vocational activities. The scientific observations therefore helped establish the contextual significance of the grind-size categories before students used them for statistical analysis. This supports the view that context-based learning can facilitate mathematization by enabling students to move between real phenomena, representations, and mathematical reasoning (Zulkardi & Putri, 2019; Zulkardi et al., 2020; Rawani et al., 2023).

The activity also illustrates the potential of STEM integration to create continuity between empirical observation and mathematical representation. Students observed a phenomenon, documented characteristics, compared categories, and subsequently used related categorical data to reason statistically. Although the primary learning objective concerned mode, the sequence encouraged students to understand that mathematical data are connected to phenomena and decisions rather than existing independently of them. This integration is consistent with research emphasizing the value of connecting mathematics with scientific observation and authentic practical contexts (Dierdorp et al., 2014; Nursyahidah et al., 2025b).

## Constructing Mode as a Basis for Decision-Making

The mathematical activity represented the culmination of the learning trajectory. Students organized preference data into a frequency table, compared the frequencies of the seven grind-size categories, and identified medium as the category with the highest frequency. The distribution consisted of 1 selection for extra fine, 3 for fine, 5 for medium fine, 9 for medium, 6 for medium coarse, 4 for coarse, and 2 for extra coarse. Students consequently identified medium as the mode because it had the highest frequency.

More importantly, students were subsequently asked to interpret the result within a coffee-shop context. Their responses indicated that they understood the medium grind size as the most frequently selected option and therefore as a potential recommendation for a menu or standard preparation. One student justified the recommendation by referring both to the number of selections and to the perceived balanced taste of the medium grind. This response is significant because it demonstrates movement beyond procedural identification toward contextual interpretation. Students used the statistical result as evidence for a practical recommendation, which is an important component of mathematical literacy (Stacey, 2014; OECD, 2023; Risdiyanti et al., 2024).

This finding also illustrates the distinction between knowing the mode and understanding what the mode communicates. In the former, students identify the category associated with the largest frequency. In the latter, they interpret that frequency distribution in relation to a decision or situation. The present learning trajectory supported this transition by requiring students to explain the practical meaning of the mode after determining it. Such an approach is consistent with research emphasizing the importance of contextual interpretation in statistics learning rather than limiting students' learning to computational procedures (Cazorla et al., 2023; Landtblom, 2023; Rahayu & Putri, 2021).

## PMRI-STEM Integration and Mathematical Literacy

Taken together, the four activities established a progression from vocational experience, observation, data representation, statistical reasoning, to contextual decision-making. This progression corresponds closely to the PMRI movement from situational understanding through model-of and model-for representations toward more formal mathematical knowledge. At the same time, the STEM components provided the practical and empirical experiences through which the mathematical problem emerged.

The engineering and technology activities generated the initial variation in grind sizes; the science activity provided opportunities to observe and interpret differences among the resulting coffee samples; and the mathematics activity transformed preference information into a frequency distribution and statistical conclusion. Consequently, the STEM components were not simply added as separate activities but functioned as contextual resources that supported the development of the mathematical concept. This is an important characteristic of meaningful STEM integration, in which disciplinary knowledge contributes to a shared problem or activity rather than being taught as disconnected components (Dierdorp et al., 2014; Geitz & de Geus, 2019).

The trajectory is also consistent with the principles of local instructional theory in design research. Students' informal observations and contextual strategies were progressively reorganized into mathematical representations that supported more formal reasoning (Gravemeijer & Cobb, 2013; Armiati et al., 2022; Zulkardi et al., 2020). The frequency table, in particular, changed function during the learning process: it first served to organize contextual data and subsequently became a tool for comparing categories, identifying the mode, and supporting a practical recommendation. This changing role of the representation provides evidence of students' progression in mathematical reasoning rather than merely their acquisition of a statistical procedure.

The coffee-grinder context also established a direct connection between statistical reasoning and the students' vocational domain. The activities involved equipment, coffee preparation, sensory evaluation, customer preferences, and menu-related decisions, all of which are recognizable within Culinary Arts education. Mathematics was therefore positioned as a resource for interpreting information and supporting decisions within a vocational practice. Previous research similarly indicates that mathematics learning situated in authentic professional practices can strengthen connections between mathematical concepts and students' future occupational contexts (Dierdorp et al., 2014; Geitz & de Geus, 2019; Fisher et al., 2020; Zhang, 2018). Overall, the findings suggest that the PMRI-STEM learning trajectory supported students in developing both procedural and contextual understanding of mode. Students were able to identify the category with the highest frequency, but they also interpreted that category as an indicator of majority preference and used it to justify a practical recommendation. This distinction is central to mathematical literacy because it involves moving from obtaining a mathematical result to interpreting and using that result in a meaningful situation (Stacey, 2014; Putri & Zulkardi, 2020; Zulkardi et al., 2020; Risdiyanti et al., 2024).

Finally, the main contribution of the study, therefore, lies not merely in presenting coffee grinding as a novel context for teaching mode, but in demonstrating how a vocationally authentic context can function as a vehicle for progressive mathematization. Through the integration of PMRI and STEM, students moved from manipulating a familiar vocational tool and observing its products to organizing categorical data, identifying the mode, and using the resulting information to support a contextual decision. This learning trajectory provides a potential model for designing statistics learning in vocational mathematics education in which mathematical concepts are developed through authentic practices and subsequently connected to formal mathematical reasoning.

## Conclusion

This study developed a PMRI-STEM-based learning trajectory for the concept of mode using a coffee grinder context relevant to Culinary Arts Vocational High School students. The trajectory integrated engineering, technology, science, and mathematics activities to guide students from direct vocational experiences toward formal statistical reasoning. The findings indicate that students were able to identify mode as the category with the highest frequency and, more importantly, interpret it as an indicator of majority preference that can inform contextual decision-making. The learning trajectory also supported students' mathematical literacy by engaging them in organizing categorical data, constructing and interpreting frequency tables, identifying the mode, and using statistical information to justify decisions in a vocational context. These findings suggest that integrating PMRI and STEM within an authentic vocational setting can provide a meaningful pathway for connecting statistical concepts with students' practical experiences and prospective workplace practices.

Several limitations should nevertheless be acknowledged. The learning trajectory was implemented with a relatively small group of students in a single Culinary Arts Vocational High School, limiting the transferability of the findings to other populations and vocational settings. In addition, the study focused specifically on mode and did not examine how the learning trajectory could be extended to other measures of central tendency or broader statistical concepts. The findings primarily describe students' learning processes and emerging understanding rather than provide evidence of statistically measured gains in mathematical literacy.

Future research could therefore extend the trajectory to mean, median, and other statistical concepts and investigate how these concepts can be integrated with different vocational practices and contexts. Studies involving multiple classes, schools, or vocational specializations could examine the adaptability of the trajectory across settings. Further research could also employ longitudinal or mixed-methods designs to investigate changes in students' mathematical literacy more systematically and to determine how sustained PMRI-STEM learning influences their ability to interpret and use statistical information in authentic vocational decision-making.

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## Conflicts of Interest

The authors declare that no conflict of interest regarding the publication of this manuscript.

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