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Integrating ethnomathematics and ethnomodeling in Institutionalization of school mathematics concepts: A study of fishermen community activities

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Abstract

While previous studies have extensively explored ethnomathematics, the relationship between ethnomathematics and ethnomodeling remains underexamined. This study investigates the connections between ethnomathematics and ethnomodeling and their implications for the institutionalization of mathematics in the context of traditional fish auction activities within the Fishermen's Community in Indramayu, Indonesia. Utilizing an ethnographic design, the study involved participants in various auction roles, including auctioneers, boat owners, captains, crew members, and traders. Data were collected through interviews and observations and analyzed using content analysis. The findings reveal that ethnomathematical practices are evident in sorting and grading fish, as well as in auction transactions, with connections to mathematical concepts such as set theory, basic statistics, social arithmetic, and arithmetic operations within an ethnomodeling framework. These results suggest that the integration of ethnomathematics and ethnomodeling into the school curriculum could support the institutionalization of mathematics education and provide a foundation for developing instructional materials based on these practices in the context of traditional fish auctions.

Keywords: Ethnomathematics, Ethnomodeling, Fishermen's Community, Fish Buying and Selling Activities, Institutionalization of School Mathematics

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The Indramayu fishing community primarily relies on fishing as its main source of livelihood. However, the activities of these fishermen extend beyond mere fishing. They are actively engaged in various commercial endeavors within traditional fishing markets. These markets serve not only as centers for trading fish and other marine products but also as vibrant environments where ethnomathematical practices emerge and flourish (Nurjanah et al., 2021).

The exploration of ethnomathematical connections in market trading practices has been extensively documented in the mathematics education research agenda. In Indonesia, several studies have investigated these connections within traditional market settings. For instance, Supit et al. (2023) examined ethnomathematical practices in the Iman Tomohon Traditional Market, revealing that traders commonly round up prices when selling goods. They provide change by first collecting cash to the nearest tenth and then summing it to match the buyer's payment. Similarly, Mardia et al. (2020) conducted a study on the Marosok trading tradition of the Minangkabau tribe in West Sumatra, uncovering mathematical representations through finger symbols and gestures that convey basic numbers, including one, two, three, four, five, and two and a half, as well as fundamental arithmetic operations like addition and subtraction.

Further research by Malalina et al. (2022) explored the application of mathematical concepts in itinerant trading along the Musi River. Their findings indicated that mobile trading practices on the river inadvertently introduce several mathematical concepts, such as solid figures (sphere, cube), plane figures (rectangle), comparisons, social arithmetic, and systems of linear equations. Additionally, Angraini and Rakhmawati (2023) investigated the activities of fish traders at the Punggulan Village Traditional Market. Their study identified three primary activities—measuring, packaging, and buying and selling—each involving mathematical concepts such as measurement, sets, one-variable linear equations, weight comparisons, social arithmetic, relations and functions, two-variable linear equations, plane figures, and probability. Finally, Sudirman et al. (2023) explored the unique calculation methods employed by traditional traders, highlighting their use of a backward calculation technique, which contrasts with the conventional methods taught in schools.

The findings from existing research reveal a significant gap in the study of ethnomathematics within market trading practices, as investigations have largely been confined to the examination of calculation symbols, counting activities, and the shapes of tools used in trade. Moreover, while there have been studies focused on the buying and selling of fish, these have generally concentrated on the broader act of trading fish and have not specifically addressed the nuanced processes involved in fish auctions at traditional fish auction sites.

Ethnomathematics, however, extends beyond mere trade transactions and is deeply embedded in various aspects of daily life across different cultures. In Africa, for instance, ethnomathematical practices are reflected in the cultural artifacts of the Akan tribe in Ghana, including earthenware, mortars, buildings, and batik, which represent geometric concepts related to planes and spaces (Owusu-Darko et al., 2023). Similarly, the Kafa people of Ethiopia utilize mathematical concepts such as base six numbers (maqoo), a base sixty counting system (Uddoo), fractions, and measurement in their agricultural activities (Gebre et al., 2021). Chahine (2021) explored the forecasting practices of Ilm al-raml in Egypt, revealing an algorithmic system based on the principles of Boolean algebra and a probabilistic sequence of events designed to predict future outcomes.

In South America, the cultural context of ethnomathematics is evident in various community activities, including cooking (Rodríguez-Nieto & Escobar-Ramírez, 2022), making mud bricks (Pabón-Navarro et al., 2022), planting oil palms (Rodríguez-Nieto et al., 2022), fishing (Mansilla-Scholer et al., 2022), and trading (Rodríguez-Nieto et al., 2022). Additionally, it is seen in architectural forms (Orey, 2000), as well as in sacred mat patterns and Mayan diamond geometric shapes (Rosa & Orey, 2008).

Furthermore, in Asia, ethnomathematical values are equally diverse. For example, Indonesian batik patterns embody geometric shapes (Prahmana & D'Ambrosio, 2020). The Pranatamangsa system and birth-death ceremonies in Indonesia represent integer counting operations (Prahmana et al., 2021). Artifacts from traditional buildings illustrate geometric concepts of planes and spaces (Sudirman et al., 2020; Supiyati et al., 2019; Fauzi et al., 2022). Other practices include the Cigugur indigenous community's method of selecting auspicious days for building a house (Umbara et al., 2021a) and the process of making traditional Barongko cakes, which involves mathematical concepts of division, congruence, equality, and the use of triangular and hemispherical prisms (Pathuddin et al., 2021).

The current body of research demonstrates that ethnomathematics has been extensively explored in various trade practices and other facets of daily life across different countries. However, the focus of these studies has predominantly been on buying and selling transactions, calculation methods, and the tools used in trading. Additionally, research has primarily examined beliefs, values, and artifacts related to buildings, traditional agricultural practices, and traditional cake-making.

Despite these insights, there remains a notable gap in the literature regarding the application of ethnomathematics to fish auctions at traditional auction sites. Specifically, no previous studies have addressed the ethnomathematical aspects of buying and selling fish within auction contexts. Furthermore, there has been a lack of research on institutionalizing the mathematical concepts derived from fish auctions in traditional settings.

In recent years, the field of ethnomathematics has undergone significant development, particularly with efforts to integrate it into school mathematics curricula (Fouze & Amit, 2017; Zhang & Zhang, 2010). This integration is a crucial advancement toward creating a more inclusive, relevant, and student-centered mathematics education (Furuto, 2014; Mosimege & Egara, 2022; Orey & Rosa, 2008; Rosa & Orey, 2021; Umeh & Rosa, 2022). By incorporating ethnomathematics, students can engage with mathematical values and concepts through the context of their own cultural experiences (Amit & Abu Qouder, 2017; Fauzi et al., 2022; Rosa & Orey, 2011). This approach aims to bridge gaps in students' understanding and appreciation of mathematics, offering more meaningful and contextual learning opportunities (Fouze & Amit, 2017; Lidinillah et al., 2022; Sunzuma & Maharaj, 2020; 2021).

Despite these advancements, there remains a notable paucity of research connecting ethnomathematics and ethnomodeling specifically to the practice of buying and selling fish at auctions, as well as to the institutionalization of these concepts within school mathematics curricula. Consequently, this research aims to explore and elucidate the connections between ethnomathematics, ethnomodeling, and their impact on the institutionalization of mathematics, particularly within the context of fish auction activities observed in the Fishermen's Community in Indramayu, Indonesia.

This research employs ethnomathematics to examine the mathematical activities involved in auction-based buying and selling practices. The concept of ethnomodeling is applied to analyze mathematical modeling in both fish sorting and grading activities as well as in fish auction processes. In the sorting and grading of fish, the research focuses on basic statistical modeling and aggregate operations related to the pricing of fish for auction. Conversely, in the auction activities, the study utilizes social arithmetic modeling to address aspects such as determining the initial price, managing price bids, and identifying the auction winner.

Furthermore, the ethnographic analysis conducted in this research extends beyond merely examining mathematical symbols or activities associated with auction transactions. It also explores how these activities contribute to the development of mathematical models. These models serve as a context for understanding school mathematics. The research also investigates mathematical practices within fish auctions in coastal fishing communities, recognizing that auction-based buying and selling is a deeply ingrained cultural practice in these areas, such as in Indramayu. This practice not only facilitates the trade of marine catches but also embodies significant social and cultural values in the daily lives of fishermen and coastal communities.

METHODS

Research Design

This study employs an ethnographic design, as described by Spradley (2016), which serves as a methodological tool for understanding the symbols embedded within a society's culture. In the context of this research, the exploration of ethnomathematical connections arises when communities ascribe meaning to mathematical concepts or objects, establish relationships between expression and content, and embed these mathematical elements within cultural practices and daily life (Rodríguez-Nieto, 2021). Such universal activities in everyday practice facilitate the comprehension of mathematics within a cultural framework. Consequently, this research is guided by the framework developed by Alangui (2020), as illustrated in Figure 1.

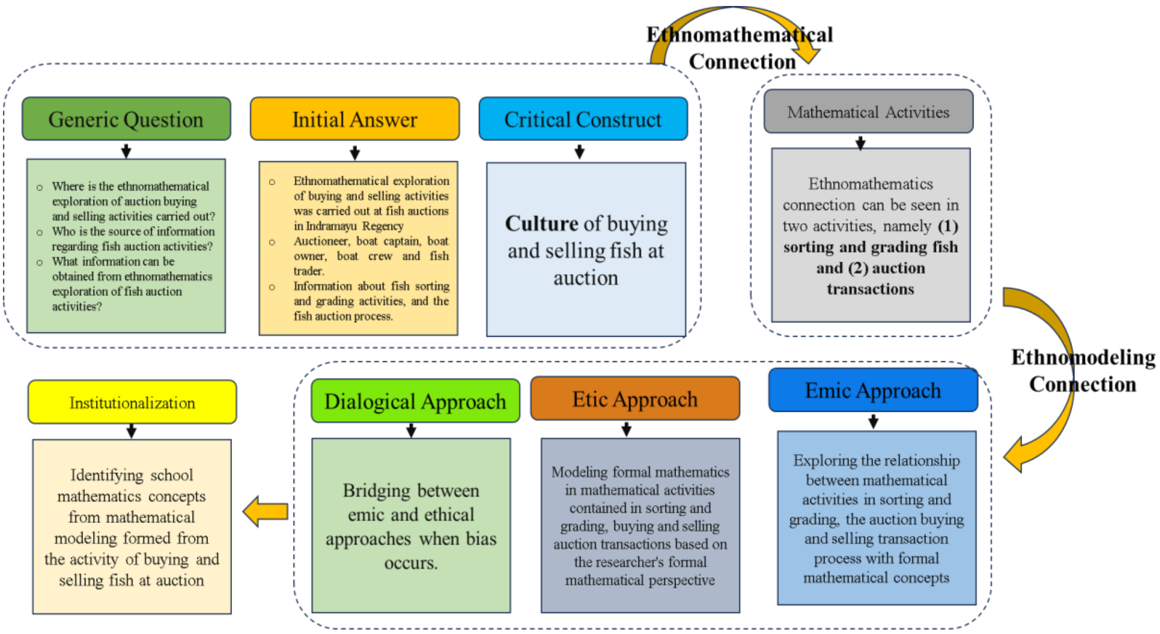


Figure 1. Ethnomathematical and Ethnomodeling Connection Framework

The ethnomathematics connection framework begins with the formulation of general questions and the development of preliminary answers. In this study, questions such as "Where does the ethnomathematical exploration of buying and selling activities occur during auctions?" and "Who are the sources of information?" are addressed. Upon obtaining initial answers, the researcher evaluates, analyzes, and refines these responses. This critical construction process results in a detailed description of the mathematical activities associated with sorting, grading, and auction-related buying and selling transactions. The process of linking these initial stages with mathematical activities is referred to as the ethnomathematical connection.

Moreover, the ethnomodeling employed in this research adheres to the three approaches outlined by Rosa and Orey (2010): the emic, etic, and dialogic approaches. The emic approach in this study examines the relationship between mathematical activities, such as sorting and grading, and the auction buying and selling process, in relation to formal mathematical concepts. The etic approach seeks to develop formal mathematical models of these activities from the researcher's formal mathematical perspective. Meanwhile, the dialogic approach aims to mediate between the emic and etic approaches to address potential biases. The integration of mathematical activities with sorting, grading, and auction transactions through these three approaches is termed an ethnomodeling connection. Additionally, this research explores the institutionalization process by identifying school-level mathematical concepts derived from the mathematical modeling of fish buying and selling activities at auctions.

Research Participants

The participants in this research comprised both primary and supporting informants. The primary informants included one auctioneer (male, 47 years old), one boat owner (male, 64 years old), one boat captain (male, 44 years old), and one auction participant/fish basket handler (male, 56 years old). The supporting informants consisted of one crew member (male, 27 years old), one retail fish trader (female, 56 years old), and one community member (female, 45 years old). All participants volunteered for this research, and no specific criteria were used to select the informants.

Data Collection

Data collection for this research involved structured non-participatory observation, semi-structured interviews, and documentation. Structured non-participatory observation was selected because the researcher did not actively participate in the observed activities. Instead, the researcher systematically observed the core activities involved in auction buying and selling, documenting processes and activities related to mathematical concepts. Observations were conducted on six occasions: once during the loading and unloading of fish from the boat to the auction site, three times during transaction activities, and twice during retail fish buying and selling activities.

Semi-structured interviews were utilized due to the flexibility they offer; while the researcher had a pre-prepared list of questions, the questions could be adapted as necessary based on the situation. In this study, 20 questions were prepared: six for auctioneers, four for boat owners, five for boat captains, two for crew members, six for auction participants, and two for retail fish traders. For example, auction participants were asked, "How do you determine the reference price for fish that will be bid at auction?" During the interviews, pseudonyms were used to maintain confidentiality, with informants labeled as I_1 through I_7 to facilitate reader comprehension. The interview questions were reviewed by a research colleague with expertise in language prior to use. Finally, documentation for this research included photographs, videos, and field notes capturing the mathematical values inherent in the fish buying and selling activities at the auction.

Data Analysis

The data analysis in this research employed a qualitative approach, which involves four stages: data collection, data reduction, data presentation, and data verification/conclusion. The qualitative analysis process began by reviewing data obtained from interviews with auctioneers, boat owners, boat captains, boat crew members, auction participants, and retail traders, along with data from observations of the auction process, which included the loading and unloading of fish from the boat to the auction site, as well as retail fish sales.

During the data reduction stage, the researchers used content analysis, following a five-step process, such as compiling interview transcripts and observation notes, constructing categories, coding interview texts and field notes, analyzing the results, and presenting the findings from the interviews and observation notes (Yaniawati et al., 2023). In this study, interview and observation transcripts were prepared with the assistance of the website https://turboscribe.ai/. The researchers then developed relevant categories, such as "mathematical activities," "sorting and grading," "price," and "buying and selling process." Furthermore, the coding process was carried out manually by inputting data into Microsoft Excel. Finally, the coded data were presented to draw conclusions. A summary of the entire data analysis process is illustrated in Figure 2.

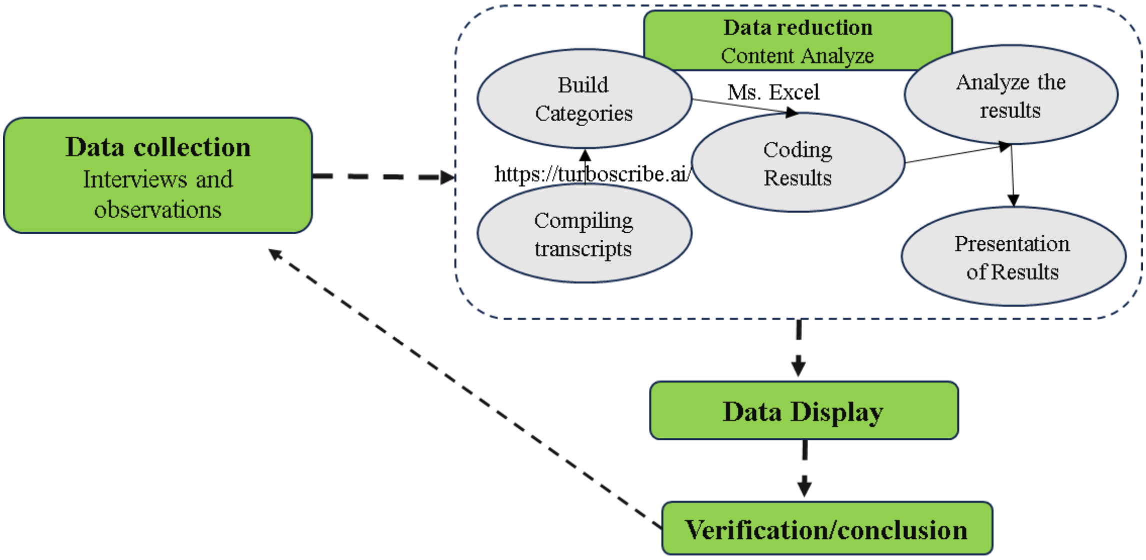


Figure 2. Data Analysis

RESULTS AND DISCUSSION

Auction Activities

Fish buying and selling activities at auctions, along with the cultural practices of the Indramayu community, embody the community's hard work and commitment to preserving traditions and fostering close connections between people, the sea, and the surrounding environment. Additionally, the auction process is rich in traditional values and local knowledge, such as selecting high-quality fish, which has been passed down through generations.

The fish auction process (see Figure 3) can vary depending on the location and type of auction conducted. Typically, fishermen catch fish according to their target, transport them to a landing site such as a port, and then proceed to identify, clean, and separate the fish based on type, size, and weight. Once sorted, the fish are listed for sale through an auction, which can be conducted either openly or in a closed format. In this research, an open auction was utilized.

In the open auction process, fish that have been sorted and graded (measured and weighed) are displayed before potential buyers, who then place bids openly. The fishermen or their representatives conduct the auction, and interested buyers bid on the fish, with the bidding continuing until the highest price is reached. The final selling price is determined by the highest bid, and the fishermen have the option to accept or reject the offer. Following the auction, the buyer pays the fisherman according to the agreed-upon price. The fishermen then deliver the fish to the buyers as per the terms of the agreement. Throughout this process, the auction organizers document and report all transactions, providing fishermen with proof of payment and transaction records.

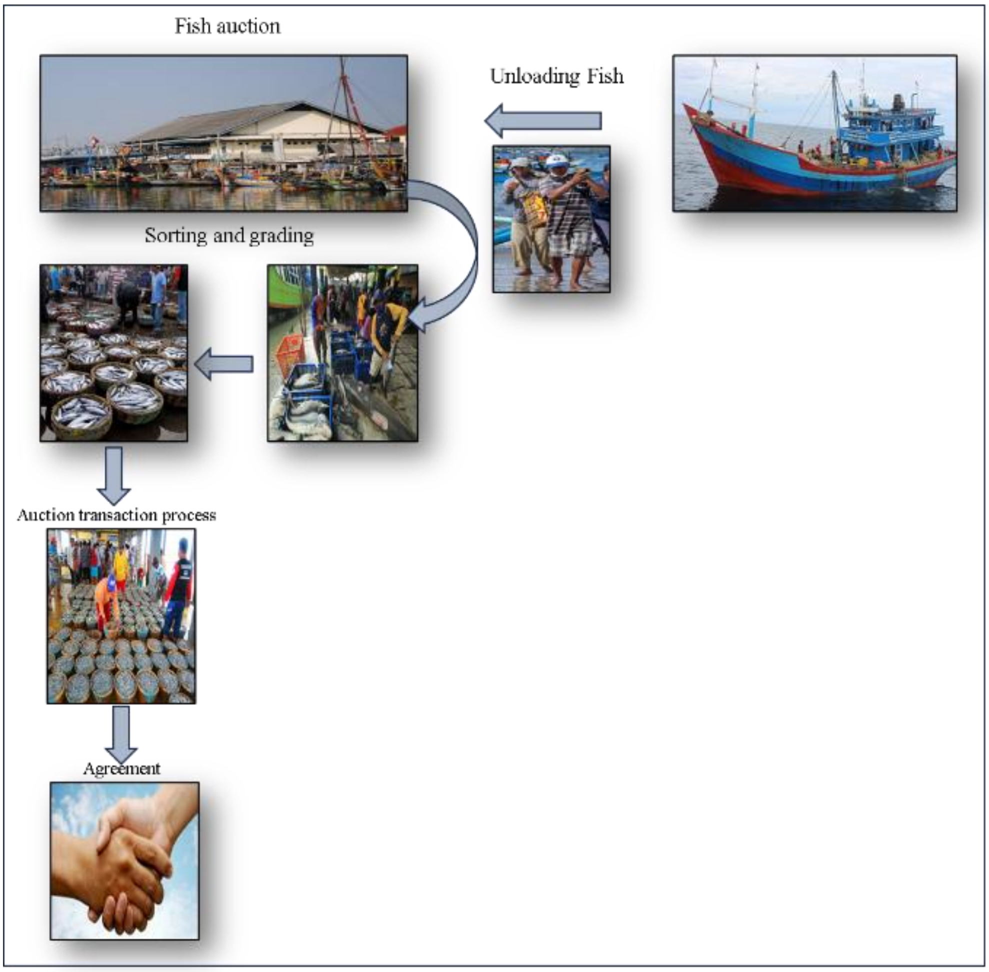


Figure 3. Auction Activities

Connection of Ethnomathematics, Ethnomodeling, and Institutionalization of School Mathematics in Fish Sorting and Grading Activities

Based on interviews with I_1, I_2, and I_3, as well as direct observations, it was found that there is a wide variety of fish with differing sizes and weights. The price of each fish is significantly affected by market demand, which in turn is influenced by factors such as the quality, size, and weight of the fish.

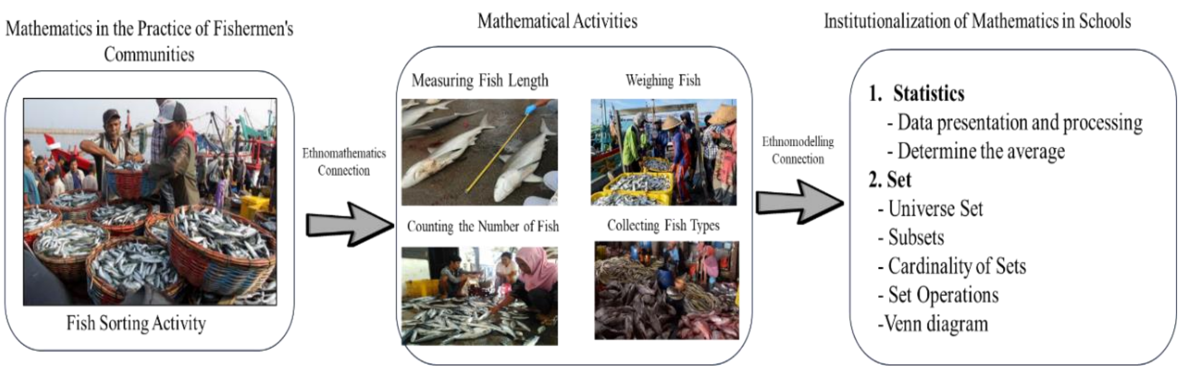


Figure 4. The Ethnomathematical and Ethnomodeling Connection between Fish Sorting and Grading Activities with Statistics and Sets

Apart from that, based on the transcript excerpt with I_1, as follows:

Researcher : What is the method used to identify the type and price of the fish?
I_1 : By using sorting and grading
Researcher : How do you sort and grade?
I_2 : There is no special event; just look at the size and type of fish, separate them, and then put them in a basket.

In the sorting and grading activities, mathematical values are represented through the measurement of fish length and weight. At traditional fish auctions in Indramayu, the sorting and grading process is performed using visual estimation rather than modern equipment (see Figure 4). Although this method is subjective, it has been demonstrated to be both precise and efficient. Fish of various types are sorted into different containers based on their length and weight. Each 5 cm increase in fish length influences the price offered by fishermen. Additionally, the fish in the containers are weighed to determine their net weight for auction. This weighing is accomplished using a hanging scale that accounts for the weight of the container.

Furthermore, fish counting is conducted, particularly for species with smaller quantities. The researchers employ three approaches to analyze ethnomodeling in the sorting and grading process: emic, etic, and dialogic. They gather information from fishermen and other relevant parties. The results of the sorting and grading activities are organized into a frequency distribution table, which includes size, fish code, weight, and quantity of fish. For example, barracuda fish measuring 32 cm are categorized within the 31-40 cm interval. These measurements and weights are recorded in Table 1.

Table 1. Fish Sorting and Grading Distribution List

Barracuda Size (cm)	Code	Weight (Kg)	Number of Fish	Cakalang Ize (cm)	Code	Weight (Kg)	Number of Fish	Ukuran Tuna (cm)	Code	Weight (Kg)	Number of Fish	Ukuran Tengiri (cm)	Code	Weight (Kg)	Number of Fish
31-40	A_1	45	228	11-20	B_1	150	1653	24- 34	C_1	1000	6000	41-50	D_1	560	2800
41-50	A_2	60	182	16-20	B_2	200	1803	35-44	C_2	459	2295	51-60	D_2	1000	4000
51-60	A_3	110	220	21-25	B_3	540	3780	45-54	C_3	345	1380	61-70	D_3	450	1350
61-70	A_4	400	350	26-30	B_4	500	3002	55-64	C_4	400	1200	71-80	D_4	349	698
71-80	A_5	86	72	31-35	B_5	2200	11015					81-90	D_5	560	560
81-90	A_6	76	49	36-40	B_6	1000	4021					91-100	D_6	679	565
91-100	A_7	1000	450	41-45	B_7	400	1202					101-112	D_7	500	346
Total		1777				4990				2204				4098	

Based on Table 1, baskets participating in the auction can calculate the average weight $(\bar{x})$ of their coded fish by dividing the total weight of the basket (W) by the number of fish (N) for each code. Calculating the average size of the fish helps the basket determine the number of fish per kilogram and estimate the price per kilogram. For instance, if a fish with code A1 weighs 0.2 kg, it implies that there are five barracuda fish of code A1 in one kilogram. This calculation assists baskets in making informed bids during the fish auction.

Barracuda Fish	Skipjack Fish	Tuna fish	Mackerel fish
$\bar{x}_{A_1} = \frac{W_1}{N_1} = \frac{45}{228} = 0.2$	$\bar{x}_{B_1} = \frac{W_1}{N_1} = \frac{150}{1653} = 0.09$	$\bar{x}_{C_1} = \frac{W_1}{N_1} = \frac{1000}{6000} = 0.17$	$\bar{x}_{D_1} = \frac{W_1}{N_1} = \frac{560}{2800} = 0.2$
$\bar{x}_{A_2} = \frac{W_2}{N_2} = \frac{60}{182} = 0.33$	$\bar{x}_{B_2} = \frac{W_2}{N_2} = \frac{200}{1803} = 0.11$	$\bar{x}_{C_2} = \frac{W_2}{N_2} = \frac{459}{2295} = .2$	$\bar{x}_{D_2} = \frac{W_2}{N_2} = \frac{1000}{4000} = 0.25$
$\bar{x}_{A_3} = \frac{W_3}{N_3} = \frac{110}{220} = 0.5$	$\bar{x}_{B_3} = \frac{W_3}{N_3} = \frac{540}{3780} = 0.14$	$\bar{x}_{C_3} = \frac{W_3}{N_3} = \frac{345}{1380} = 0.25$	$\bar{x}_{D_3} = \frac{W_3}{N_3} = \frac{450}{1350} = 0.33$
$\bar{x}_{A_4} = \frac{W_4}{N_4} = \frac{400}{350} = 1.14$	$\bar{x}_{b_4} = \frac{W_4}{N_4} = \frac{500}{3002} = 0.17$	$\bar{x}_{C_4} = \frac{W_4}{N_4} = \frac{400}{1200} = 0.33$	$\bar{x}_{D_4} = \frac{W_4}{N_4} = \frac{349}{698} = 0.5$
$\bar{x}_{A_5} = \frac{W_5}{N_5} = \frac{86}{72} = 1.19$	$\bar{x}_{B_5} = \frac{W_5}{N_5} = \frac{2200}{11015} = 0.20$		$\bar{x}_{D_5} = \frac{W_5}{N_5} = \frac{560}{560} = 1$
$\bar{x}_{A_6} = \frac{W_6}{N_6} = \frac{76}{49} = 1.55$	$\bar{x}_{B_6} = \frac{W_6}{N_6} = \frac{1000}{4021} = 0{,}24$		$\bar{x}_{D_6} = \frac{W_6}{N_6} = \frac{679}{565} = 1.20$
$\bar{x}_{A_7} = \frac{W_7}{N_7} = \frac{1000}{450} = 2.22$	$\bar{x}_{B_7} = \frac{W_7}{N_7} = \frac{400}{1202} = 0{,}33$		$\bar{x}_{D_7} = \frac{W_7}{N_7} = \frac{500}{346} = 1.44$

Following the sorting and grading process, the fish are placed into containers and sorted by type. This process involves applying the concept of sets. The universe of discourse, in this case, is the total catch of fish from the boat. Furthermore, the first set, denoted by U, includes all types of fish that have been caught. The fish types are categorized into sets A, B, C, and D. These sets represent collections of fish based on their type and size. The number of members in each set A, B, C, and D is summarized as follows:

$A = \{A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8\}$
$n(A) = 8$
$B = \{B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8\}$
$n(B) = 8$
$C = \{C_1, C_2, C_3, C_4\}$
$n(C) = 4$
$D = \{D_1, D_2, D_3, D_4, D_5, D_6, D_7, D_8\}$
$n(D) = 8$

A, B, C, and D members are also a set, as follow.

$A_1 = \{a_1, a_2,,,,,,a_{228}\}$	$B_1 = \{h_1, h_2,,,,h_{1653}\}$	$C_1 = \{o_1, o_2,,,,,,o_{6000}\}$	$D_1 = \{s_1, s_2,,,,,,_{2800}\}$
$n(A_1) = 228$	$n(B_1) = 1653$	$n(A_1) = 6000$	$n(D_1) = 2800$
$A_2 = \{b_1, b_2,,,,,,b_{182}\}$	$B_2 = \{i_1, i_2,,,,,,i_{1803}\}$	$C_2 = \{p_1, p_2,,,,,,p_{2295}\}$	$D_2 = \{t_1, t_2,,,,,,t_{4000}\}$
$n(A_2) = 182$	$n(B_2) = 1803$	$n(C_2) = 2295$	$n(D_2) = 4000$
$A_3 = \{c_1, c_2,,,,,,c_{220}\}$	$B_3 = \{j_1, j_2,,,,,,j_{3780}\}$	$C_3 = \{q_1, q_2,,,,,,q_{1380}\}$	$D_3 = \{u_1, u_2,,,,,,u_{1350}\}$
$n(A_3) = 220$	$n(B_3) = 3780$	$n(C_3) = 1380$	$n(D_3) = 1350$
$A_4 = \{d_1, d_2,,,,,,d_{350}\}$	$B_4 = \{k_1, k_2,,,,,,k_{3002}\}$	$C_4 = \{r_1, r_2,,,,,,,r_{1200}\}$	$D_4 = \{v_1, v_2,,,,,,v_{698}\}$
$n(A_4) = 350$	$n(B_4) = 3002$	$n(C_4) = 1200$	$n(D_4) = 698$
$A_5 = \{e_1, e_2,,,,,,,,e_{72}\}$	$B_5 = \{l_1, l_2,,,,,,,,l_{11015}\}$		$D_5 = \{w_1, w_2,,,,,w_{560}\}$
$n(A_5) = 72$	$n(B_5) = 11015$		$n(D_5) = 560$
$A_6 = \{f_1, f_2,,,,,,,,,f_{49}\}$	$B_6 = \{m_1, m_2,,,,f_{4021}\}$		$D_6 = \{x_1, x_2,,,,,,,x_{565}\}$
$n(A_6) = 49$	$n(B_6) = 4021$		$n(D_6) = 565$
$A_7 = \{g_1, g_2,,,,,,g_{450}\}$	$B_7 = \{n_1, n_2,,,,,,n_{1202}\}$		$D_7 = \{y_1, y_2,,,,,,y_{346}\}$
$n(A_7) = 450$	$n(B_7) = 1202$		$n(D_7) = 346$

To determine the combination of all types of fish, use the combination concept.

$U = A \cup B \cup C \cup D$
$= \{\{A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8\}, \{B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8\}, \{C_1, C_2, C_3, C_4\},$
$\{D_1, D_2, D_3, D_4, D_5, D_6, D_7, D_8\}\}$

If illustrated in a Venn diagram, it looks like Figure 5.

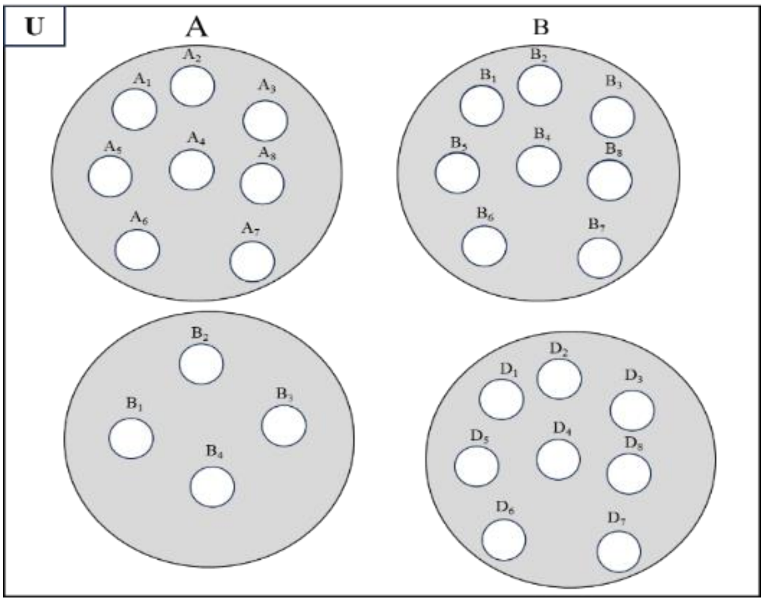


Figure 5. Vennn Diagram

Next, to determine the number of members of the set U using the concept of cardinality by adding the number of members of each set.

$n(A) = n(A_1) + n(A_2) + n(A_3) + n(A_4) + n(A_5) + n(A_6) + n(A_7)$
$= 228 + 182 + 220 + 350 + 72 + 49 + 450$
$= 1551$
$n(B) = n(B_1) + n(B_2) + n(B_3) + n(B_4) + n(B_5) + n(B_6) + n(B_7)$
$= 1653 + 1803 + 3780 + 3002 + 11015 + 4021 + 1202$
$= 26476$
$n(C) = n(C_1) + n(C_2) + n(C_3) + n(C_4)$
$= 6000 + 2295 + 1380 + 1200$
$= 10875$
$n(D) = n(D_1) + n(D_2) + n(D_3) + n(D_4) + n(D_5) + n(D_6) + n(D_7)$
$= 2800 + 4000 + 1350 + 698 + 560 + 565 + 346$
$= 10319$
$N(U) = n(A) + n(B) + n(C) + n(D)$
$= 1551 + 26476 + 10875 + 10319$
$= 49221$

Mathematical modeling of the sorting and grading processes used by fishing communities has traditionally relied on intuitive methods and experiential knowledge to visually differentiate fish based on size, type, or physical quality. This approach typically involves basic statistical concepts and set operations. In contrast, modern methods use advanced technologies such as image processing machines, optical sensors, or artificial intelligence algorithms to sort and grade fish according to specific criteria, such as size, weight, or quality.

Connection of Ethnomathematics, Ethnomodeling, and Institutionalization of School Mathematics in Fish Auction Activities

Based on observations and interviews with I_1, fish buying and selling transactions at the auction are generally conducted openly. Buyers, known as *bakul*, compete directly to purchase the fish. An excerpt from the interview with I_1 is as follows:

Researcher : What is the process of determining the initial price and winner of the fish auction?
I_1 : Usually, the one with the most extensive offer is chosen
Researcher : Usually, there is a price benchmark based on fish needs. If the weather is good, fish stocks are usually abundant, and the price can go down, but if the weather is not good, the price of fish will go up.
Researcher : How is the fish auction process carried out in this place?
I_1 : Usually, the boat owner contacts the auction committee to sell the boat catch that will be docked on a specific date to the auction committee. After the boat is docked, the fish are collected at the auction site. If the fish stock is empty, it is usually immediately sorted and graded for immediate sale. Auction participants generally monitor the arrival of the boat. After that, start the auction.

Further observations of auction activities at fish auction sites in Indramayu, Indonesia, reveal that the *bakul*, who are generally women over 50 years old with little formal education, participate in the process. Despite its seemingly simple nature, the fish auction transaction involves various mathematical activities. These activities include determining the initial price, calculating bids, identifying the winning bid, managing bids, and converting fish weight measurements (see Figure 6).

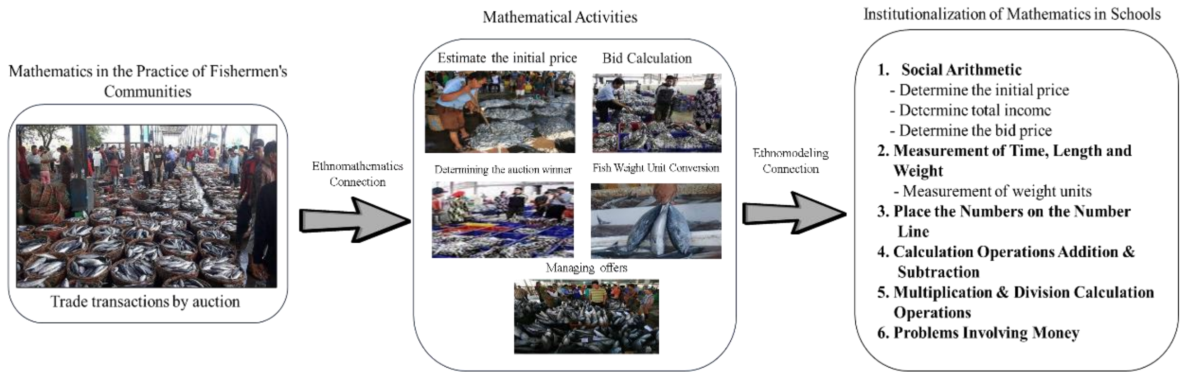


Figure 6. Ethnomathematics and Ethnomodeling Connection to Fish Auction Activities

Based on interviews with I_1 and I_2, it is customary for them to estimate the initial price or base price of the fish before the auction begins. This estimation is influenced by variables such as previous market prices, the type and condition of the fish, availability, weather conditions, and other factors. For instance, tuna is typically caught during the dry or east season from March to August. If tuna is caught in abundance, its price may decrease. The mathematical values involved in setting this initial price include social arithmetic, counting operations, and measurements of fish weight and price.

Following the determination of the initial price, I_1 meticulously manages the bidding process, recording the minimum price increments between fish baskets. At the end of the auction, I_1 tallies the highest bids to identify the winner and calculates the total auction revenue, accounting for fish sales, taxes, and other fees. The mathematical activities performed by I_1 and I_2 are designed to secure the best possible selling price for the fish while ensuring fairness for both fishermen and fish baskets. The mathematical values in these activities include social arithmetic, counting operations, and measurements of fish weight and price.

When I_2 makes an open offer for the fish, the *bakul* (buyers) begin to place bids. According to I_4, they first perform calculations to determine an appropriate offer price. I_4 considers factors such as fish type and quality, operational costs, transportation expenses, and desired profit margins. These calculations ensure that the purchase price of each fish is reasonable and allows for profitable resale. Since fish are typically bought in large quantities, I_4 must also convert fish weight into suitable units to determine the price per kilogram or other units. Thus, the mathematical values in this activity include social arithmetic, counting operations, and measurements of fish weight and price.

The subsequent process involves meticulous management of fish stocks, including calculations to forecast customer demand, assess available inventory, and plan additional purchases if needed. The mathematical values in this stage also involve social arithmetic, counting operations, and measurements of fish weight and price. To integrate ethnomodeling, the approaches used include emic, etic, and dialogical perspectives. Mathematical modeling is represented in determining the initial price, managing bidding prices, and identifying the winner of the fish auction, though it does not include conversions of fish weight and length units.

Starting Price

There is no fixed mathematical formula that can be used in general to determine the initial price in a fish auction because the initial price (I_p) is greatly influenced by various factors such as market price (M_p), operational costs (C_o), and profit margin (P_m). The market price is the current price. Operational costs are costs incurred to run the auction, such as venue costs, employee salary costs, and administration costs. Profit margin is the percentage of profit the auctioneer desires from selling fish. In simple terms, the initial price is calculated using a formula.

$$Initial\ Price = (Market\ Price + Operating\ Costs) + Profit\ Margin$$

$$I_p = \left(M_p + O_p\right) + P_m$$

Current market prices tend to fluctuate. However, every fish auction place has fish price updates every month. For example, the current price of tuna is around IDR 22,000/Kg. The operational costs for one kg of fish are IDR 300, while the desired profit margin is 10% of the market price. Therefore, the initial price for the offer is:

$$I_p = (M_p + O_p) + P_m$$
$$= (22{,}000 + 300) + \left(22{,}000\, x \left(\frac{10}{100}\right)\right)$$
$$= (22{,}300) + (2{,}200)$$
$$= 24{,}500$$

So, the initial price for one kg of tuna offered at auction is IDR 24,500/Kg.

Management of Fish Bidding and Determination of Auction Winners

To manage offers, use the interval concept from the initial price to the highest price requested by fish baskets.

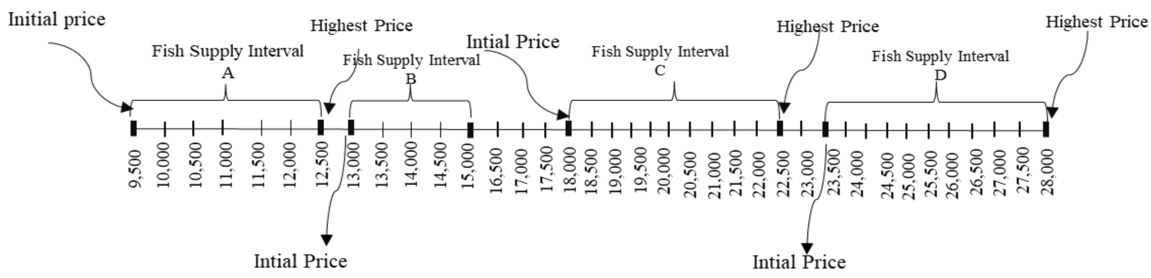


Figure 7. Fish Supply Price Interval

As an illustration, if the initial price of fish A is IDR 9,500/kg, the increase in supply is 500/kg, and the highest price is IDR 12,500, then the illustration can be presented in Figure 7. Each supply point corresponds to the price of fish in one kg. Apart from that, mathematically managing fish supply uses the concept of a number line (See Table 2).

Table 2. Fish Supply Number Line

Types of Fish	Offer Interval	Notation	Number Line	Interval Type
Fish A	$9{,}500 \leq x \leq 12{,}500$	[9,500 – 12,500]	9,500 – 12,500	Close Interval
Fish B	$13{,}000 \leq x \leq 14{,}500$	[13,000 – 14,500]	13,000 – 14,500	Close Interval
Fish C	$18{,}000 \leq x \leq 22{,}500$	[18,000 – 22,500]	18,000 – 22,500	Close Interval
Fish D	$23{,}000 \leq x \leq 28{,}000$	[23,000 – 28,500]	23,500 – 28,5000	Close Interval

In the situation of offering fish, a with an initial price of 9,500 and a maximum price of 12,500, it falls into the closed interval category, written as $9{,}500 \leq x \leq 12{,}500$ and notated [9,500 – 12,500]. Furthermore, the bid with the highest price will be selected as the winner. This means that to determine the winner, they are selected based on the maximum price. In general, the concept of the number line in the bidding process can be written as follows.

$$[a, b] = \{x | a \leq x \leq b\}$$

Bid Calculation

I_4 before starting the offer, I_4 has determined the highest price that can be purchased. The highest benchmark price (Z) is based on component costs, such as operational costs (X_1), basic price of fish (X_2), and desired profit (Y). In simple terms, this can be formulated as follows:

Highest Benchmark Price = Σ (Component Costs) + Desired Profit

$$Z = (X_1 + X_2) + Y$$

Operational costs (X_2) per kilogram are calculated by adding up transportation costs (Tc), storage costs (S_c), and other costs (O_c), then dividing the results by the total fish (T_f) to be purchased.

$$Operating\ costs = \frac{Transportation\ costs + Storage\ costs + \ Other\ costs}{Total\ fish\ to\ be\ purchased}$$

$$X_2 = \frac{T_c + S_c + O_c}{T_f}$$

As an illustration, if a basket person buys 8 tons (8,000 kg) of fish, the transportation costs are IDR 1,000,000, the storage costs are IDR 500,000, and other costs are IDR 500,000, then the operational costs per/kg of fish are:

$$\begin{aligned} X_2 &= \frac{T_c + S_c + O_c}{T_f} \\ &= \frac{1{,}000{,}000 + 500{,}000 + 500{,}000}{8{,}000} \\ &= \frac{2{,}000{,}000}{8{,}000} \\ &= 250 \end{aligned}$$

So, the operational cost per/kg is IDR 250. Furthermore, if a basket person wants to buy 8 tons (8,000 kg) of fish A, the operational cost per/kg is IDR 250, the base price of fish A is 12,000/kg, and the desired profit per/kg 20% of the base price of fish, then the highest benchmark price is:

$$\begin{aligned} Highest\ Benchmark\ Price &= (12{,}000 + 250) + (20\%\, x\, 12{,}000) \\ &= 12{,}250 + 2{,}400 \\ &= 14{,}650 \end{aligned}$$

So, the highest benchmark price for baskets is 14,650. After knowing the highest benchmark price, baskets can start offering fish from prices below IDR 14,650.

Fish Weight Unit Conversion

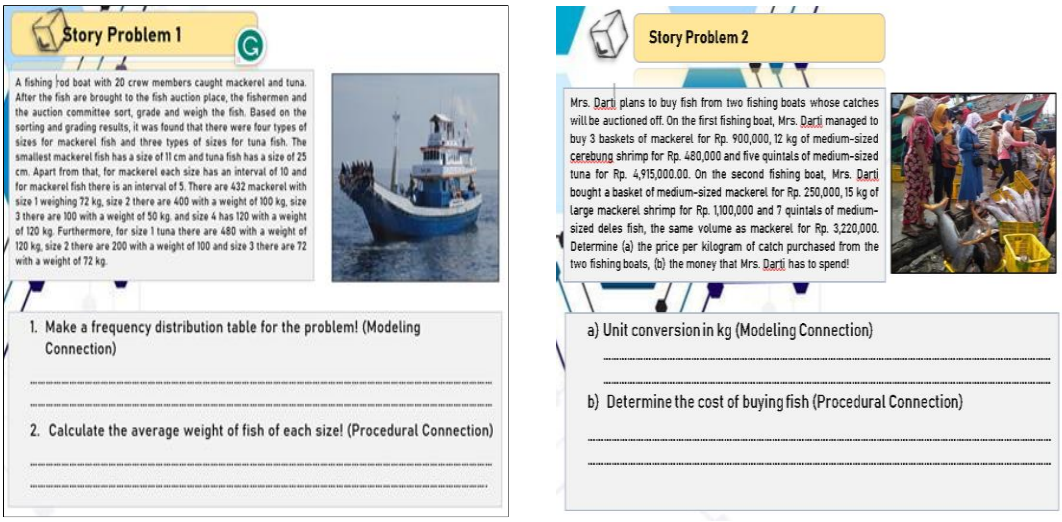
Based on information from I_4, in the world of weighing fish, various weight units commonly used can be seen in Table 3.

Table 3. Fish Weight Unit

No	Unit weight	Conversion
1	Kilogram	The common weight unit used to measure the weight of fish in most countries around the world.
2	Ons	At the fish auction in Indramayu, 1 ounce is equivalent to 0.1 kg. Generally used to sell shrimp, squid, anchovies.
3	Quintal	The quintal is a larger unit than the kilogram, where one quintal is equal to 100 kilograms.
4	Tons	The ton is a much larger unit than the kilogram, where one ton is equal to 1,000 kilograms.
5	Basket	At the fish auction in Indramayu, 1 basket is equivalent to 30 kg.

Institutionalization of Mathematics in Schools

The establishment of institutionalization of mathematics in schools from the context of buying and selling fish online in the Indramayu fishing community was carried out by integrating it into didactic situations (See Figure 8).



(i) (ii)

Figure 8. The Didactic Situation of School Mathematics

Problem 1 serves as an introductory exercise for understanding fundamental statistical concepts at the elementary or junior high school level. To address Problem 1 (see Figure 8), students begin by identifying the type, weight, and quantity of fish for each size category. Specifically, the mackerel species includes four size categories, whereas the tuna species encompasses three size categories. The smallest mackerel measures 11 cm in length, and the smallest tuna measures 25 cm in length. Following this identification process, students are required to construct a mathematical model for each fish species in the form of a frequency distribution table. For mackerel, the frequency distribution table will feature four rows corresponding to the four size categories of mackerel, with columns representing the weight and quantity of fish for each size. Similarly, the frequency distribution table for tuna will consist of three rows representing the three size categories, with columns denoting the weight and quantity of fish for each size. The structure of the frequency distribution tables for each fish species is illustrated in Figure 9.

Mackerel/Size	Weight (Kg)	Number of Mackerel
11 cm		
....		
....		
....		
.....		

Tuna/Size	Weight (Kg)	Number of Tuna
25 cm		
......		
.....		
.....		

Figure 9. List of Frequency Distributions for Each Type of Fish

Didactically, in Problem 1, the process of correlating fish size, fish weight, and the number of fish to construct a frequency distribution is referred to as connection modeling. Conversely, the process of associating the weight of the fish with its quantity to calculate the average weight of tilapia for each size category is termed procedural connection (see Figure 10).

Moreover, Problem 2 (see Figure 8) serves as an introduction to the concepts of social arithmetic for elementary or junior high school students. This problem involves determining the initial purchase price of the seafood bought by Mrs. Darti. To solve this problem, students must first identify the type of seafood Mrs. Darti purchased from each boat. Subsequently, students should convert the quantities from standard units to kilograms. Following this, students can calculate the unit price for each type of seafood purchased by Mrs. Darti. Didactically, in Problem 2, the process of relating the measurements used by Mrs. Darti to standard units (kg) is termed modeling connection. Conversely, the process of calculating the initial unit price of each type of seafood is referred to as procedural connection (see Figure 10).

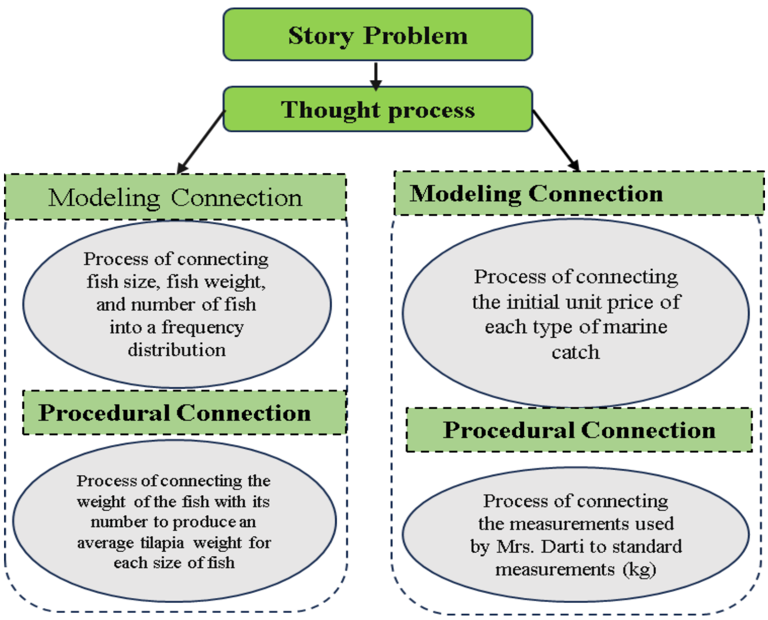


Figure 10. Didactic Process

Discussion

Ethnomathematics examines how different cultures integrate mathematical practices with cultural contexts, social environments, politics, and economics, applying these practices to relevant everyday situations. While numerous studies have investigated ethnomathematics within buying and selling practices, there is a lack of research focusing specifically on auction transactions in Indramayu. This study distinguishes itself by concurrently employing both ethnomathematics and ethnomodeling methodologies, offering a novel approach compared to previous research.

This research identified that ethnomathematics connections manifest in the auction-based fish buying and selling practices within the Indramayu Fishermen's Community. Specifically, ethnomathematics is evident in fish sorting and grading activities, including tasks such as measuring fish length, weighing fish, counting the number of fish, and categorizing fish by type. The integration of ethnomodeling into these sorting and grading activities can facilitate the institutionalization of school mathematics, encompassing concepts such as sets (universe sets, subsets, set cardinality, set operations, and Venn diagrams) and statistics (data collection and presentation, averages).

Furthermore, ethnomathematical connections to auction transactions are evident in activities such as estimating initial prices, managing bids, determining auction winners, calculating bid amounts, and converting fish weight. Ethnomodeling contributions to auction transactions can aid in the institutionalization of school mathematics, including topics such as materials, social arithmetic, weight measurements, number line placements, arithmetic operations (addition, subtraction, multiplication, division), and monetary problem-solving. These findings are detailed in the research framework (see Figure 11).

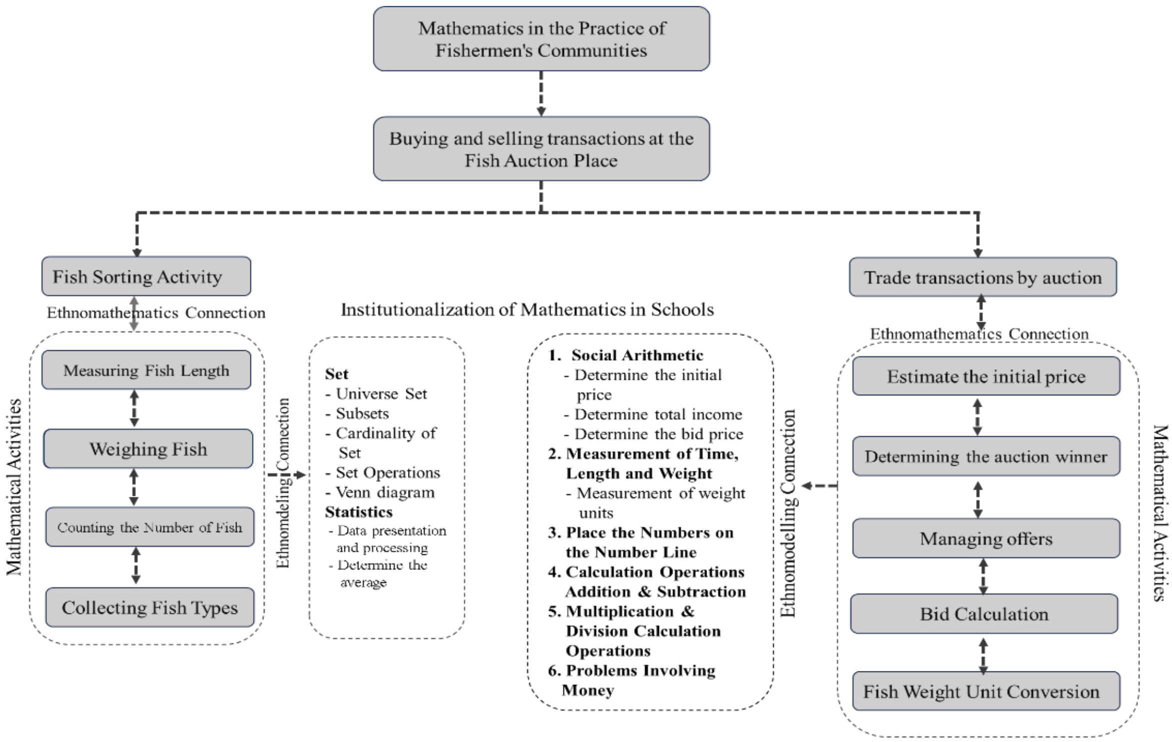


Figure 11. Framework of Research Findings

Research on ethnomathematics in trading practices frequently reveals that many mathematical activities occur in everyday life with limited conscious awareness from those involved. This phenomenon illustrates the longstanding integration of mathematics into cultural and economic activities. For instance, Nurjanah et al. (2021) documented that the Minangkabau Tribe in Indonesia employs mathematical representations through finger symbols and body movements for calculation activities. On the other hand, Sudirman et al. (2023) observed that traders in traditional markets utilize the "backward calculation" method to determine the remaining change. Additionally, Angraini and Rakhmawati (2023) identified that the community of Asahan Regency organizes fish trading activities in traditional markets into three main processes: measuring, packaging, and buying and selling. These processes encompass various mathematical concepts, including measurement, sets, one-variable linear equations, weight comparisons, social arithmetic, relations and functions, two-variable linear equations, planar geometry, and probability.

In traditional auction-based fish buying and selling, one of the most prominent ethnomathematics connections is observed in counting activities. Counting, as a significant aspect of ethnomathematics, varies widely depending on cultural practices, traditions, community environments, geographic conditions, and levels of education. Nurjanah et al. (2021) found that the Minangkabau people of Indonesia utilize finger-based calculations in traditional buying and selling activities. Similarly, Wiryanto et al. (2022) and Janiola and Santo (2021) discovered that traditional calculations are integral to determining calendars in Indonesian and Filipino cultures. Umbara et al. (2021a; 2022b) documented that the Cigugur indigenous people in Indonesia use calculations to identify auspicious days for construction and optimal times for farming. Additionally, the Kafa community in Ethiopia employs calculations within their agricultural practices (Gebre et al., 2021), and in Nigeria, traditional calculations are used in the production of fired bricks (Abah et al., 2020). This counting process not only addresses the practical needs of auction-based fish transactions but also embodies local wisdom and community knowledge. The Indramayu fishing community, in particular, relies heavily on experiential knowledge and intuition for observing, estimating, sorting, and grading fish, as well as determining appropriate pricing for their catch.

This research aims to advance the institutionalization of mathematics in schools by implementing didactic situations that involve auction activities with coastal communities in Indramayu. This approach introduces key mathematical concepts such as sets, social arithmetic, and statistics. The application of didactic situations rooted in societal culture has garnered significant attention in mathematical education research. For example, Risdiyanti et al. (2019) developed a Learning Trajectory based on the traditional Indonesian game *Kubuk Manuk* to facilitate students' understanding of social arithmetic. Similarly, Sukestiyarno et al. (2023) employed the traditional fishing tool "Bubu" to teach concepts of non-Euclidean geometry. Malalina et al. (2022) utilized the trade practices on the Musi River in Palembang, Indonesia, to enhance students' grasp of social arithmetic. Additionally, Susanti (2021) demonstrated that the local game Tong Tong Galitong Ji can aid in comprehending arithmetic operations, probability, and arithmetic sequences. Prahmana and Istiandaru (2021) identified various engaging elements and patterns within Javanese *Wayang Kulit*, which can serve as a foundation for studying the concept of assemblage. Their research highlights those students successfully developed an understanding of congruence and congruent triangles through an ethnomathematics-based learning process centered on Islamic ornaments.

This research demonstrates that connections between ethnomathematics and ethnomodeling can facilitate the institutionalization of mathematical concepts within educational settings. Ethnomathematics, by relating mathematical practices to everyday life, provides insights into how various cultures approach counting, measuring, weighing, identifying, collecting, and solving mathematical problems. Furthermore, integrating ethnomathematics into didactic situations drawn from students' cultural backgrounds enhances their understanding of mathematical concepts. This approach aligns with Rodríguez-Nieto's (2021) assertion that ethnomathematics can be understood as the relationship between mathematics practiced within cultural groups and the universally recognized mathematical concepts found in curricular materials, such as textbooks. In the context of this research, the connection between ethnomathematics and auction-based fish buying and selling activities leads to the development of mathematical tasks, including measuring, weighing, identifying, calculating, collecting, and managing auction results, thereby reflecting practical mathematical activities.

Furthermore, the connection between ethnomodeling and cultural mathematical activities supports students in linking cultural practices with mathematical modeling, thereby enhancing their mathematical understanding. This perspective is consistent with Umbara et al. (2021b), who highlight the central role of ethnomodeling in bridging cultural aspects with mathematical modeling, facilitating its application in educational settings. Additionally, ethnomodeling contributes to problem-solving and understanding alternative mathematical systems (Rosa & Orey, 2016) and offers an integrative approach to the school mathematics curriculum by incorporating both emic and etic knowledge through a dialogical approach (Cortes & Orey, 2020). In this research, the ethnomodeling connection within auction-based fish buying and selling activities leads to the development of mathematical models for sorting, grading, and transaction processes. Future research could further investigate the interplay between ethnomathematics, ethnomodeling, and the institutionalization of mathematics across diverse cultural and social contexts. Such studies would deepen the understanding of how mathematics can be integrated with local cultural practices. Moreover, this research offers opportunities for the development of learning modules based on these findings, which could serve as independent resources for students or supplementary materials for classroom instruction.

CONCLUSION

The fish buying and selling activity conducted through an auction system is a long-standing cultural tradition among the Indramayu people, maintained since ancient times. This auction-based fish trade extends beyond mere commercial transactions for fishermen; it is deeply embedded in local traditions, social interactions, and cultural events, representing an integral aspect of the fishermen's way of life and local heritage. Among the cultural heritage practices is the mathematical activity associated with fish auctions. Theoretically and conceptually, such activities fall under the domain of ethnomathematics. Within the Indramayu Fishermen's Community, ethnomathematics connections are evident in both fish sorting and grading activities, as well as auction transactions. Specifically, ethnomathematics manifests in tasks such as measuring fish length, weighing fish, counting fish, and categorizing them by type. Ethnomodeling, in turn, facilitates the integration of school mathematics through concepts such as sets (including universe sets, subsets, set cardinality, set operations, and Venn diagrams) and statistics (such as data collection, presentation, and averages). Additionally, ethnomathematical connections to auction transactions involve estimating initial prices, managing bids, determining auction winners, calculating bid amounts, and converting fish weights. These ethnomodeling connections contribute to the institutionalization of school mathematics, including topics such as materials, social arithmetic, weight measurements, number line placements, arithmetic operations (addition, subtraction, multiplication, division), and monetary problem-solving.

This research concludes that the institutionalization of mathematics in educational settings can be effectively achieved by integrating ethnomathematics and ethnomodeling practices observed in fishing communities' fish buying and selling activities. Additionally, mathematical concepts in the school curriculum can be taught through didactic situations, such as auction transactions, which facilitate the understanding of concepts including sets, social arithmetic, and statistics. Involving students' everyday cultural contexts in the teaching of mathematical concepts allows them to construct these concepts based on their personal experiences. This approach helps students perceive mathematics as relevant to their everyday lives, rather than as an abstract theory disconnected from their experiences. Consequently, mathematical concepts that may initially seem challenging or abstract become more comprehensible as students recognize direct connections between these concepts and real-life situations.

This research has several limitations. Firstly, it is confined to the examination of fish buying and selling activities conducted through auctions in Indramayu, Indonesia, which may limit the generalizability of the findings to other regions. Additionally, the focus on the institutionalization of school mathematics concepts is restricted to those identified through the connections between ethnomathematics and ethnomodeling within these traditional auction practices. Furthermore, the study employs an ethnographic approach to explore and understand the relationship between ethnomathematics, ethnomodeling, and school mathematical concepts in the context of fish auctions in Indramayu. This approach may not fully capture all aspects of these relationships or provide a comprehensive analysis. Consequently, feedback and further research from other scholars are essential to address these limitations and enhance the depth and applicability of the findings.

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Declarations

Author Contribution	:	S: Conceptualization, Methodology, Formal Analysis, Investigation, Resources, Data Curation, Writing-Original Draft, Editing, and Visualization. CAR-N: Writing-Review & Editing, Formal analysis, and Methodology. EB: Review, Validation and Supervision.
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Additional Information : Additional information is available for this paper.

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