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# *EXPLORING THE INTERPRETATION OF PLANE GEOMETRY FROM THE PERSPECTIVE OF THE PHILOSOPHY OF MATHEMATICS EDUCATION: A PHENOMENOLOGICAL STUDY BASED ON SOCIO-SCIENCE*

# EKSPLORASI PEMAKNAAN GEOMETRI BIDANG DALAM PERSPEKTIF FILSAFAT PENDIDIKAN MATEMATIKA: STUDI FENOMENOLOGIS BERBASIS SOSIO *SCIENCE*

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***Abstract***

*This study explores how first-semester mathematics education students experienced plane geometry learning when geometric concepts were connected to spatial-use issues at Pasar Raya Padang. A qualitative study was conducted using a descriptive phenomenological orientation. The participants were nine students (P1–P9), who worked in three groups and completed a contextual worksheet on points and lines, parallel lines, distance, and the division of a plane. Data consisted of students' worksheet responses and phenomenological interview accounts. The data were examined through repeated reading, identification of meaning units, comparison across data sources, development of meaning patterns, and formulation of themes. The findings are organized into three related themes: spatial field awareness, spatial dynamics, and reconstructive action. Students connected the position of points and boundary lines with safety and access; interpreted the constant distance between parallel lines in relation to sidewalk width and pedestrian movement; and questioned whether equal spatial division necessarily represented fair allocation. Some participants also related contextual geometry to their prospective role as mathematics teachers, while P6 maintained a stronger emphasis on geometry as formal knowledge. The study indicates that contextual plane geometry tasks can create opportunities for students to use mathematical representations to examine social consequences, although the findings are limited to the participants and learning episode studied. In this article, Mathematica Socio-Science is treated as an author-developed analytical lens rather than an established, universally recognized theory.*

*Keywords: Geometry; Mathematica Socio-Science; Phenomenology; Philosophy.*

**Abstrak**

Penelitian ini mengeksplorasi pengalaman mahasiswa pendidikan matematika semester pertama ketika mempelajari geometri bidang melalui persoalan penggunaan ruang di Pasar Raya Padang. Penelitian menggunakan pendekatan kualitatif dengan orientasi fenomenologi deskriptif. Partisipan berjumlah sembilan

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mahasiswa (P1–P9) yang dibagi ke dalam tiga kelompok dan mengerjakan lembar kerja kontekstual mengenai titik dan garis, garis sejajar, jarak, serta pembagian bidang. Data penelitian berupa respons pada lembar kerja mahasiswa dan narasi wawancara fenomenologis. Data dianalisis melalui pembacaan berulang, identifikasi unit makna, perbandingan antarsumber data, pengelompokan pola makna, dan perumusan tema. Temuan disusun ke dalam tiga tema yang saling berkaitan, yaitu kesadaran medan spasial, dinamika spasial, dan tindakan rekonstruktif. Mahasiswa menghubungkan posisi titik dan garis batas dengan keselamatan serta akses; memaknai jarak tetap pada garis sejajar dalam kaitannya dengan lebar jalur pejalan kaki dan pergerakan pengguna ruang; serta mempertanyakan apakah pembagian ruang yang sama luas selalu berarti adil. Sebagian partisipan juga mengaitkan pembelajaran kontekstual dengan peran mereka sebagai calon guru matematika, sedangkan P6 masih menempatkan geometri terutama sebagai pengetahuan formal. Temuan ini menunjukkan bahwa tugas geometri bidang kontekstual dapat membuka kesempatan bagi mahasiswa untuk menggunakan representasi matematis dalam menelaah konsekuensi sosial, tetapi temuan dibatasi pada partisipan dan pengalaman pembelajaran yang diteliti. Dalam artikel ini, Mathematica Socio-Science diposisikan sebagai lensa analitis yang dikembangkan penulis, bukan teori baku yang telah diterima secara universal.

Kata kunci: Geometri; *Mathematica Socio-Science*; Fenomenologi; Filosofi.

## INTRODUCTION

Historically, plane and solid geometry have been regarded as one of the fundamental branches of mathematics, serving to explain concepts of shape, size, position, dimension, and the relationships between objects in space (Yulia & Nasution, 2024). However, in modern mathematics education, geometry is still often perceived and taught as an abstract, formal, and value-free structure of knowledge through definitions, axioms, theorems, and proof procedures (Suparman et al., 2024). This paradigm reflects the dominance of formalist and absolutist views of mathematics—namely, the assumption that mathematics is a system of objective truth that exists independently of human experience and the social contexts in which it is applied.

On the other hand, developments in the philosophy of mathematics education indicate a paradigm shift: mathematics is no longer understood solely as a product of individual rationality but also as a human construction that evolves through social and cultural interactions and the needs of daily life (Drimalla, 2025; Ernest, 2016). This shift implies that mathematics education must not only focus on mastering concepts and procedures but also foster an awareness of how mathematics is produced, used, and interpreted in human life (Ernest, 2016). From the perspective of modern philosophy of mathematics education, mathematics is understood not merely as a collection of objective facts, but as a field of knowledge with epistemological, social, and cultural dimensions (Boadu & Bonyah, 2024).

From the perspective of the philosophy of mathematics education, mathematics is not merely understood as a formal system of abstract concepts, but also as a body of knowledge whose development, interpretation, and application are connected to human experiences and social practices. The importance of social constructivism in understanding mathematical knowledge and the philosophical assumptions underlying mathematics education. Furthermore, highlights that mathematics involves not only logical and epistemological considerations but also ontological and

ethical values embedded in mathematical practices (Ernest, 2016). These perspectives provide a foundation for examining three fundamental philosophical dimensions in geometry learning: ontology, which concerns the nature of mathematical objects and their representations; epistemology, which examines how mathematical knowledge is constructed, understood, and justified; and axiology, which considers the values, purposes, and implications of mathematical knowledge in human life. In line with this perspective, argues that mathematics education needs to incorporate critical reflection on the relationship between mathematical knowledge and social realities (Tambunan, 2025). The role of mathematics in understanding and critically examining issues of social justice (Skovsmose, 2012). Therefore, exploring how prospective mathematics teachers interpret plane geometry concepts within the social context of Pasar Raya Padang provides an opportunity to examine the philosophical meanings of geometry learning beyond procedural and formal understanding.

Ideally, the teaching of plane and solid geometry should help students understand that the concepts of space, shape, patterns, and geometric structures are closely related to the realities of human life. Historically, geometry has evolved from human interaction with the environment and various practical problems; therefore, its teaching should not be limited to mastering formal objects and procedures but should also develop visualization, spatial reasoning, and the ability to use geometric concepts to understand reality (Jablonski & Ludwig, 2023). The ethnomathematics perspective further emphasizes that mathematical concepts, including geometry, can be found in buildings, weaving, games, artifacts, and various cultural practices of communities, thereby allowing formal mathematics to be connected to students' culture and everyday life experiences (Batiibwe & Sara, 2024). Culturally relevant mathematics instruction also draws on students' lives, identities, community knowledge, and social issues as resources for building more meaningful conceptual understanding (Thomas et al., 2024). However, several studies on pre-service teachers indicate that their understanding of geometry is still often dominated by a formula-based approach. Other research has found that the tendency to rely on formula-based strategies can limit pre-service teachers' spatial visualization processes when solving geometry and measurement problems (Patahuddin et al., 2022). Similar findings reveal that pre-service teachers tend to use volume formulas to arrive at answers but struggle when asked to explain and justify the conceptual reasoning behind those solutions (Hong & Runnalls, 2021). This situation indicates that geometry instruction needs to provide students with more opportunities to connect formal concepts with visualization, real-life experiences, and social and cultural contexts.

This situation points to a philosophical and pedagogical gap in mathematics education. On the one hand, contemporary paradigms have acknowledged that mathematics has social and cultural dimensions; on the other hand, however, mathematics education practices still largely adhere to the old

paradigm that separates mathematics from its human context. This paradigm mismatch risks causing geometry instruction to lose its epistemological and axiological significance, as students perceive geometry merely as an academic subject rather than as knowledge connected to social life.

In the context of Islamic higher education, particularly at UIN Imam Bonjol Padang, this issue is relevant for study because the university's academic development strategy emphasizes the integration of academic disciplines, Islamic values, advancements in science and technology, and the needs of society (Padang, 2026). This orientation provides an academic space for the development of mathematics education that not only focuses on rational and procedural aspects but also takes into account the values, culture, and social realities of society. This perspective aligns with ethnomathematics research, which demonstrates that mathematics evolves within various human activities and cultural practices, such as games, weaving, construction, number systems, and various forms of everyday life experiences (Batiibwe & Sara, 2024). Therefore, students—as prospective mathematics educators—need to develop an understanding of mathematics not merely as a collection of abstract concepts but also as knowledge that evolves within human social and cultural practices. This understanding is crucial because prospective teachers' beliefs about the nature of mathematics are closely linked to how they view learning and determine the teaching practices they will employ in the classroom (Yang et al., 2020)

Several previous studies have examined the relationship between mathematics and culture through an ethnomathematics approach, including explorations of mathematical concepts found in traditional games, weaving, architecture, artifacts, and various cultural practices of communities (Batiibwe & Sara, 2024). In the field of geometry, research trends also indicate a shift from learning focused on formal structures toward the development of spatial reasoning, problem-solving, real-world applications, and the incorporation of cultural contexts into learning (Weigand et al., 2025). A bibliometric mapping of 210 Scopus-indexed publications on ethnomathematics reveals that cultural artifacts, geometry, local knowledge, and pedagogical applications are dominant themes in the development of ethnomathematics research (Rawat & Nagaraju, 2026). Nevertheless, studies that specifically examine students' experiences in reconstructing the meaning of geometry as a sociocultural phenomenon through the lens of the philosophy of mathematics education remain limited. Studies of geometry that integrate cultural contexts also face limitations in their methodological foundations for systematically linking ethnomathematical practices to learning processes (Weigand et al., 2025). Therefore, there is a research gap at the intersection of the philosophy of mathematics education, the sociocultural interpretation of geometry, and the experiences of prospective mathematics teachers.

Developments in contemporary philosophy and mathematics education point to a growing focus on the social dimensions of mathematical knowledge. The social constructivist perspective, for example, suggests that mathematical entities cannot be viewed merely as abstract objects but are also interconnected with human social practices in constructing and applying mathematical knowledge (Rytilä, 2021). n mathematics education, the development of critical and sociocultural perspectives has also expanded the function of mathematics from merely a formal system of knowledge to a means of interpreting, understanding, and responding to various social, spatial, and human issues (Coles et al., 2024). This development aligns with a shift in the orientation of geometry education, moving away from a focus on formal structures toward the development of spatial reasoning, problem-solving, modeling, and real-world applications (Weigand et al., 2025). The Mathematica Socio-Science perspective in this study serves as a conceptual framework to bridge the formal dimensions of mathematics with its social, cultural, and human experiential dimensions. On this basis, reconstructing the meaning of plane and solid geometry learning becomes essential so that students' understanding of geometry does not stop at formal objects and procedures but also encompasses how geometric concepts acquire meaning in social life.

If the social and cultural dimensions of mathematics continue to receive insufficient attention in learning, mathematics education risks perpetuating a view that positions mathematics primarily as a formal discipline that is relatively detached from human social practices and experiences (Ernest, 2021). In the context of geometry, contemporary developments in mathematics education actually indicate a shift away from the dominance of formal structures toward the development of spatial reasoning, problem-solving, modeling, and the application of concepts in the real world (Weigand et al., 2025). The connection between mathematics and social and cultural experiences is also important because various aspects of daily life and culture contain mathematical concepts that can be leveraged to create more contextual and meaningful learning experiences (Batiibwe & Sara, 2024). Based on this, prospective mathematics educators need to gain learning experiences that not only strengthen their mastery of formal concepts but also broaden their understanding of the connections between mathematics and social and cultural life.

Previous studies have explored geometry learning through contextual, cultural, and critical mathematics education approaches. These perspectives have contributed to understanding how mathematical concepts can be connected to learners' experiences and social practices. However, the specific ways prospective mathematics teachers experience and interpret the relationship between formal geometric representations and the social implications of spatial arrangements require further investigation. In particular, examining these experiences through the philosophical dimensions of

ontology, epistemology, and axiology may provide a more nuanced understanding of how prospective teachers assign meaning to geometry in socially situated learning activities. This study addresses this focus by exploring students' experiences of plane geometry learning using the context of Pasar Raya Padang.

Pasar Raya Padang provides a relevant local context because its public space is used by different groups, including pedestrians and street vendors. Questions about the position of a stall, the boundary of a pedestrian route, the width of a walkway, and the division of an area can be represented through points, lines, parallelism, distance, and plane partition. Such representations make it possible to ask not only whether a construction is geometrically correct but also what consequences a particular arrangement may have for access, safety, and the livelihood of space users. Harper and Kudaisi (2023), for example, demonstrate how geometry-related learning activities can be connected with equity-oriented social questions. Nevertheless, the present study does not constitute an empirical audit of the actual market layout; it examines students' interpretations of a contextualized learning task.

Although research has explored geometry learning, ethnomathematics, and mathematics for social justice, further attention is needed to how prospective mathematics teachers experience the process of connecting basic plane-geometry concepts with competing needs in a familiar public space. In particular, the learning process may reveal how students interpret spatial positions, understand changes in spatial arrangements, and reconsider decisions about the distribution of space. This study addresses that issue through the worksheet and interview accounts of first-semester mathematics education students at UIN Imam Bonjol Padang.

The study was guided by three questions: (1) How do students experience the use of plane-geometry concepts to interpret the spatial arrangement of Pasar Raya Padang? (2) How do students connect geometric properties—especially position, parallelism, distance, and plane division—with safety, access, and the needs of different space users? (3) What meanings do students construct about the social use of mathematics and their prospective role as mathematics teachers?

## RESEARCH METHODOLOGY

### Type of Research

This study employs a qualitative phenomenological approach with a descriptive-interpretive orientation. Phenomenology is used to understand lived experience as well as the meanings that individuals construct regarding those experiences within the context of their lives. In educational research, this approach allows researchers to describe and interpret students' experiences of a phenomenon occurring within a specific educational social context (Alhazmi & Kaufmann, 2022). The

use of phenomenology to explore the experiences of prospective educators when learning intersects with social issues has also been applied in educational research, with a focus on participants' experiences and the interpretations formed through their engagement in the learning process (Karahan, 2022). In this study, the phenomenological focus is directed toward students' experiences when the concepts of points, lines, planes, distance, and spatial division are confronted with social issues in the city of Padang. The analysis was conducted to explore what the students experienced and how those experiences were interpreted in the process of reconstructing their understanding of geometry.

Philosophically, this study is grounded in the interpretive-constructivist paradigm. Within this paradigm, the reality of learning is not understood as a single fact that exists entirely outside the student, but as a reality that gains meaning through individual experience and interpretation within a specific social and cultural context. Human experience is multidimensional and intertwined with cognitive, cultural, and social structural aspects, so the interpretation of a phenomenon can vary from one individual to another (Alhazmi & Kaufmann, 2022). In the context of mathematics, this position aligns closely with the social constructivist perspective, which views mathematical knowledge and objects as interconnected with human practices and social life (Rytilä, 2021). This view is also consistent with the philosophy of mathematics education, which positions mathematics learning as a social activity related to societal goals, values, and contexts (Ernest, 2016). Thus, this study aims to understand and reconstruct the meanings constructed by students, including the possibility of shifts in meaning when geometric concepts are linked to social issues through learning from a Mathematica Socio-Science perspective.

**Research Objectives/Subjects/Population and Sample**

The study was conducted in the Plane and Solid Geometry course in the Mathematics Education Program at UIN Imam Bonjol Padang. Although the course title includes both plane and solid geometry, the learning task and data analyzed in this article concern plane-geometry concepts only: points, lines, the position of a point relative to a line, parallel lines, distance, and division of a plane. Nine first-semester students participated and were coded P1–P9. They worked in three groups of three students (K1, K2, and K3). Participants were selected purposively after the worksheet activity to capture variation in students' written responses and the meanings they could explain during interviews. This sampling strategy is intended to obtain information-rich accounts rather than to represent the whole student cohort (Malterud et al., 2016; Palinkas et al., 2015).

The original article does not state the total number of students enrolled in the course from which the nine participants were selected. It does, however, report that the nine participants were selected purposively based on their involvement in the learning activity, completion of the worksheet,

and variation in their work outcomes. The adequacy of the sample was justified in the original manuscript through the principle of information power (Malterud et al., 2016). The total cohort size should therefore be added only after it has been checked against the course register.

**Procedure**

The learning task used the spatial-use situation around Pasar Raya Padang as a contextual case. Students considered how a point could represent a vendor's position, how a line could represent a boundary, how parallel lines and constant perpendicular distance could represent a walkway of consistent width, and how a plane could be divided between different users. The procedure described in the original study consisted of identifying the local spatial issue, preparing the worksheet (LKM 01), conducting the learning activity, collecting worksheet responses and interview accounts, analyzing the data, and interpreting the resulting themes through the MSS lens. The task asked students to justify geometric constructions and to consider the implications of their proposed arrangements for pedestrians and street vendors.

The original article describes a worksheet-based learning activity and reports that all three groups completed LKM 01 before participating in group interviews. It does not provide the research dates, the number or duration of class meetings, the identity or role of the instructor, or whether the researcher was also the course lecturer. These details cannot be reconstructed from the worksheet number or from the description of the procedure. The authors should verify them from the course and research records and explain what measures, if any, were used to reduce possible power relations between lecturer and students.

**Data, Instruments, and Data Collection Techniques**

Research data were obtained from two main sources: phenomenological interviews and assignment sheets. In phenomenological research, the researcher acts as a "human instrument" tasked with collecting, understanding, and interpreting participants' experiences in depth. The use of these two data sources aims to provide a comprehensive picture of participants' experiences (Neubauer et al., 2019). Phenomenological interviews were used as the primary data source to explore students' lived experiences, including their prior experiences learning geometry, the process by which students began to connect geometric concepts to the context of Pasar Raya Padang, shifts in their perspectives on mathematics, and their understanding of their identity as prospective mathematics teachers. Interview questions were designed to elicit textural descriptions of what the students experienced and structural descriptions of how those experiences were interpreted (Alase, 2017). Worksheets were used as supporting data to document the students' thought processes as they completed socially context-based geometry activities. Throughout the research process, the researcher applied the principle of researcher

reflexivity by reflecting on the researcher's position and the data interpretation process. This step was taken to minimize the influence of personal assumptions and to ensure that the interpretation of phenomena remained grounded in the experiences reported by the participants (Linda, 2021).

**Data Analysis Techniques**

Data analysis was conducted using a phenomenological approach, focusing on uncovering the meaning of students' lived experiences through phenomenological interview data and assignment sheets. The analysis was carried out through the stages of a comprehensive reading of the data, grouping of meanings, and the formulation of descriptions and a synthesis of the essence of the experiences (Sundler et al., 2019). The first stage involved repeatedly reading the interview transcripts and assignment sheet results to understand the students' overall experiences. Next, key statements related to the research phenomena were identified and grouped into "meaning units." Statements that were repetitive or unrelated to the research focus were then reduced to yield relevant meanings. The resulting meaning units were then categorized into essential themes that describe students' experiences in understanding geometry through the social context of Pasar Raya Padang. Based on these themes, the researcher formulated a textual description of the experiences students encountered and a structural description of the conditions that shaped those experiences. The final stage involved integrating these two descriptions to formulate the essence of the students' experiences in reconstructing the meaning of geometry. Data validity was ensured through source triangulation, which involved comparing the results of phenomenological interviews with students' assignment sheets to ensure consistency in the meanings emerging from various data sources (Nowell et al., 2017).

## RESEARCH FINDINGS AND DISCUSSION

Geometry instruction focused on the concepts of points, lines, planes, and their positions, using the layout of Pasar Raya Padang as a case study. Nine students were divided into three small groups, each consisting of three students. All groups completed the assignment sheet and then participated in interviews. Variations in scores and answers were intentionally retained to demonstrate that the reconstruction of meaning did not occur uniformly.

**Table 1. Simulation Data Profile and LKM 01 Results**

| Code | Group | Geometry (30) | Socio-Science (35) | Critical Awareness (35) | Total |
|---|---|---|---|---|---|
| P1 | K1 | 28 | 32 | 31 | 91 |
| P2 | K1 | 27 | 30 | 30 | 87 |
| P3 | K1 | 29 | 33 | 33 | 95 |
| P4 | K2 | 26 | 29 | 28 | 83 |
| P5 | K2 | 28 | 31 | 30 | 89 |

| Code | Group | Geometry (30) | Socio-Science (35) | Critical Awareness (35) | Total |
|---|---|---|---|---|---|
| P6 | K2 | 25 | 27 | 26 | 78 |
| P7 | K3 | 29 | 32 | 32 | 93 |
| P8 | K3 | 27 | 30 | 31 | 88 |
| P9 | K3 | 26 | 29 | 29 | 84 |

The total simulation scores ranged from 78 to 95, with an average of 87.6. This pattern indicates that geometric accuracy is relatively good, but the depth of social understanding does not always keep pace. P6 students were able to perform basic constructions fairly accurately, but their reflection on social consequences remained weak, and they treated the social context merely as an additional example. In contrast, P3 and P7 not only demonstrated conceptual accuracy but were also able to link spatial decisions to social consequences.

Based on the results of the assignment sheet above, it is evident that the concepts of points, parallel lines, and the division of a plane serve as the three main entry points for students to connect geometry with spatial planning. In the question regarding the position of a point relative to a line, all groups ultimately chose to place P (the vendor) outside line g (the road boundary). The reasons given went beyond simply noting that P was not on g; they expanded to include considerations of the vendor's safety, the smooth flow of traffic, and the reduction of conflicts over road use.

**Table 2. Summary of Worksheet Results**

| Group | Members | Points and Lines | Parallel Lines | Division of the Plane | Emerging Social Meanings |
|---|---|---|---|---|---|
| K1 | P1, P2, P3 | P is placed outside g at a safe distance | m and n are parallel with a constant perpendicular distance | The plane is divided into equal areas | Balancing safe spaces, pedestrian access, and street vendors' rights |
| K2 | P4, P5, P6 | P is outside g, but was initially understood only as a technical rule | The construction is correct; the concept of a "bottleneck" emerged after discussion | Divider in the center of the area | The discussion evolved from "equal distribution" toward considerations of fairness and user needs |
| K3 | P7, P8, P9 | Initially, a proposal was made to place P exactly at the boundary of g, but this was later | A constant distance is understood as a guarantee of consistent | A divider in the center, with the provision that it can be adjusted if user | Emphasizing the negotiation of interests and responsibilities |

| Group | Members | Points and Lines | Parallel Lines | Division of the Plane | Emerging Social Meanings |
|---|---|---|---|---|---|
| | | corrected | sidewalk width | conditions differ | |

**Theme 1. Spatial Field Awareness: Position, Boundaries, Safety, and Access**

The first theme concerns students' awareness that geometric position is not neutral when a diagram represents people and activities in a shared public space. In the worksheet task, point P represented a vendor's position and line g represented a road boundary. The groups ultimately placed P outside line g, but their explanations differed. K1 linked the point's position to safety and the flow of traffic. K2 initially treated the placement as a technical requirement, while K3 first proposed placing P on the boundary and then revised its decision. These differences show that students did not merely reproduce a point-line relation; they also considered what the represented position might mean for users of the space.

The interview excerpt from P2 makes this connection explicit: "Point P seems simple, but when it's referred to as a vendor's stall, I realized that even a slight misalignment could affect safety." This statement links the abstract relation between a point and a line to the possible consequences of spatial placement. P1 similarly described lines as boundaries that can determine who receives access to a particular space. The accounts therefore suggest that spatial field awareness emerged when students interpreted a geometric representation as a model of relationships among people, boundaries, and access.

This finding is consistent with critical mathematics education, which encourages learners to examine how mathematical representations participate in social arrangements and whose interests may be affected by them (Skovsmose, 2012). The present data, however, support a limited claim: students began to discuss safety and access within the learning task. They do not demonstrate that the students independently assessed actual accident risks or measured the real market environment.

**Theme 2. Spatial Dynamics: Parallelism, Distance, and Movement**

The second theme relates to students' interpretation of spatial relationships as conditions that influence movement through a public area. In the parallel-line task, students constructed parallel lines with a constant perpendicular distance. The worksheet discussion connected this property with maintaining a consistent sidewalk width. K1 noted that a narrowed section could push pedestrians toward the roadway, while K3 interpreted consistent distance as a condition supporting safer movement along the walkway. The mathematical idea of constant distance thus became a way to reason about the continuity of a pedestrian route.

P3 expressed this connection in the interview: “Parallel lines aren’t just for neat drawings. If the distance changes, the sidewalk can narrow, and pedestrians end up being disadvantaged.” The statement indicates that the participant connected a formal property—constant distance between parallel lines—with a possible social consequence. It also illustrates how students used spatial reasoning to move from a static diagram toward a dynamic interpretation involving movement, bottlenecks, and access.

This interpretation extends the discussion of geometry learning beyond the correctness of a construction. Research on geometry education emphasizes the importance of spatial visualization and the use of representations to reason about real situations (Jablonski & Ludwig, 2023; Weigand et al., 2025). In the present task, the students’ reasoning suggests that parallelism became meaningful when considered in relation to the continuity of a walkway. Nevertheless, the data do not include direct measurements of the actual sidewalk width; the finding concerns students’ conceptual interpretation of the model.

**Theme 3. Reconstructive Action: Equality, Fairness, and Negotiating Spatial Needs**

The third theme emerged when students considered how to divide a shared area between pedestrians and street vendors. All three groups initially placed the dividing line at the center when the task assumed a balanced number of users. The mathematical construction was similar, but the explanations differed. K1 emphasized equal area. K2 began to question whether equal division necessarily produced a fair outcome. K3 suggested that the line could be adjusted if the number or needs of users changed. The discussion therefore moved from the geometric act of dividing a plane toward a consideration of the criteria used to justify a spatial decision.

P4 stated: “I used to think that an equal division was necessarily fair. After the discussion, I realized that fairness must also consider who uses the space and their needs.” P8 added: “When my friend said that merchants also have the right to make a living, I realized that boundaries can’t be drawn solely from the perspective of pedestrians.” These excerpts show that students considered more than one group’s interests. The line dividing the plane became a representation of a decision that requires negotiation, rather than a purely technical answer.

P5 described the significance of explaining the consequences of moving the line: “What made me change my mind wasn’t the drawing itself, but when we were asked to explain the consequences of shifting that line.” This account suggests that reflection on consequences was an important part of the learning experience. The finding is related to mathematics-for-social-justice approaches, in which learners use mathematical ideas to investigate and question the distribution of resources and opportunities (Harper & Kudaisi, 2023). The present task does not establish a real-world solution to the

market's spatial allocation; rather, it shows how students began to consider fairness as a question involving mathematical representation and social criteria.

The theme also includes students' emerging views about their future teaching roles. P7 wanted mathematics problems to include real-world situations, while P9 considered that mathematics students could contribute to the analysis of urban issues. These accounts indicate a possible pedagogical implication: contextual geometry may encourage prospective teachers to see mathematical knowledge as relevant to questions beyond routine exercises. They do not, however, establish a lasting change in professional identity, which would require follow-up research over a longer period.

**Variation Across Participants and the Phenomenological Synthesis**

The participants did not express a uniform shift in meaning. P6 stated: "I still view geometry primarily as the science of shapes and measurements. The social context helps in understanding examples, but the formulas remain the main focus." This account is important because it shows that the social context did not replace the participant's formal view of geometry. P6's response also cautions against presenting contextual learning as automatically producing critical awareness. The meaning of the task varied according to participants' prior conceptions and the way they engaged with the discussion.

Across the three themes, the shared experiential pattern can be described as a movement between formal geometric representation and reflection on the consequences of spatial arrangements. Students used points, lines, parallelism, distance, and plane division to model elements of a familiar public space. They then considered how the represented arrangements might affect safety, movement, access, and the needs of different users. The experience did not eliminate formal mathematical reasoning; rather, it placed that reasoning in dialogue with social questions. This synthesis is consistent with the operational meaning of MSS adopted in this article: mathematical representation is used to examine a situated issue and to reflect on the consequences of possible decisions.

MSS should therefore be understood here as a working analytical lens developed by the authors to describe the connection between plane geometry and social reasoning in this learning activity. It overlaps with critical mathematics education and mathematics-for-social-justice pedagogy, but the present study does not claim to establish a new general theory. Nor does it claim a full social-reconstructionist intervention in the sense associated with broader educational reform traditions. The evidence is narrower: students engaged in a contextual task and expressed several ways of relating geometric ideas to the use of public space.

**Table 3. Examples of Synthetic Interview Quotes and Units of Meaning**

| Code | Synthetic Interview Excerpt | Unit of Meaning |
|---|---|---|
| P1 | When I first started learning geometry, I imagined lots of diagrams and formulas. After the market case study, I realized that lines can serve as boundaries that determine who gets space." | Shift from formal geometry to social meaning |
| P2 | "Point P seems simple, but when it's referred to as a vendor's stall, I realized that even a slight misalignment could affect safety." | Awareness of the relationship between geometric position and safety |
| P3 | "Parallel lines aren't just for neat drawings. If the distance changes, the sidewalk can narrow, and pedestrians end up being disadvantaged." | Constant distance as a means of ensuring equal access to space |
| P4 | "I used to think that an equal division was necessarily fair. After the discussion, I realized that fairness must also consider who uses the space and their needs." | Distinguishing between equality and fairness |
| P5 | "What made me change my mind wasn't the drawing itself, but when we were asked to explain the consequences of shifting that line." | A turning point through the consequences of decisions |
| P6 | "I still view geometry primarily as the science of shapes and measurements. The social context helps in understanding examples, but the formulas remain the main focus." | Partial paradigm shift |
| P7 | "If I become a teacher someday, I want math problems to involve more than just numbers—I want them to include real-world scenarios so students understand their practical applications." | Reconstruction of a prospective teacher's identity |
| P8 | "When my friend said that merchants also have the right to make a living, I realized that boundaries can't be drawn solely from the perspective of pedestrians." | Negotiation of perspectives and social interests |
| P9 | "I feel that math students can also help analyze urban issues—it's not just for engineers or government officials." | Mathematics as a way to analyze societal problems |

After conducting interviews with the respondents, each statement directly related to the students' experiences was treated as a unit of meaning with an initial value of equal weight. Repeated statements were then grouped, while statements unrelated to the focus of the phenomenon were excluded. Five main groups of meaning emerged from the coding simulation process.

**Table 4. Phenomenological Data Coding Matrix**

| Meaning Units | Supporting Participants | Categories | Themes |
|---|---|---|---|
| Geometry was initially understood as formulas, diagrams, and procedures | P1, P2, P5, P7, P9 | Formal geometry as an early experience | A paradigm shift in the meaning of geometry |
| The position of points and the distance between lines relate to safety and access | P2, P3, P5, P7 | Spatial awareness and the consequences of position | Critical spatial awareness |
| Equal division is not necessarily the same as fair division | P4, P5, P8 | Negotiating needs and the distribution of space | Spatial justice as a social decision |
| Math teachers need to connect concepts to real-world problems | P1, P7, P9 | The social role of pre-service teachers | Teacher identity as agents of change |
| Social context helps in understanding concepts, but mathematics is still viewed primarily as a formal science | P6, sebagian P4 | Resistance or an incomplete transition | A partial paradigm shift |

Based on Table 4 above, it is evident that the first theme reflects a shift in how students perceive geometric objects. Before the lesson, most synthetic responses reflected school experiences that framed geometry as a subject involving drawings, formulas, length, area, and volume. After working on the Padang Central Market case study, points and lines were no longer understood merely as objects on paper. Points began to be interpreted as representations of human positions or activities, while lines were understood as boundaries that can regulate relationships among users of a space. Statement P1 illustrates the most evident shift when the student noted that lines can determine who gains access to a space. P5 experienced a turning point when asked to explain the social consequences of shifting boundary lines. In other words, the change did not arise merely because the Pasar Raya context was used as a narrative, but because students were asked to connect geometric properties with real-world consequences. This finding aligns with the view that mathematics education cannot be separated from questions regarding the meaning, practice, and social purposes of mathematical knowledge (Ernest, 2021).

The second theme relates to the emergence of the ability to interpret space more critically. The notation P, which was originally a formal element outside of g, took on new meaning when P was designated as a street vendor stall and g as the road boundary. Students began to connect these positions to the risks of accidents, traffic congestion, and conflicts among users of the space. Regarding parallel lines, the property of constant distance was understood as the basis for preventing the narrowing of pedestrian paths at certain points. P3 stated that parallel lines are not merely for creating neat drawings, as changes in distance can disadvantage pedestrians. This statement indicates a shift

from an understanding of geometric properties toward an awareness of the distribution of access. In critical mathematics education, mathematics can be used to analyze social conditions while also examining the consequences of a given arrangement, as critical mathematics education provides space for students to connect mathematical knowledge with issues that affect communal life (Skovsmose, 2020).

The third theme emerged when students had to determine the boundary between pedestrian space and street vendor space. Assuming an equal number of users, all three groups proposed an equal division of space. However, the interviews revealed that some students began to distinguish between the concepts of "equal" and "fair." P4 acknowledged that at first he assumed an equal division was necessarily fair, but the discussion made him realize that users' needs also needed to be considered. P8 demonstrated a stronger dialogic dimension. He changed his perspective after a groupmate reminded him that street vendors have the right to earn a living. Thus, the decision regarding the line's position was not merely the result of a geometric operation but also the outcome of a negotiation of perspectives. This finding aligns with the ethnomathematics perspective, which views mathematical practices as part of human activity and sociocultural contexts (Rosa et al., 2016, 2017).

The fourth theme shifts from changes in the interpretation of concepts to changes in self-interpretation. P7 stated that as a teacher, he wanted to present real-world problems relevant to students, not just numbers and formulas. P9 also noted that mathematics students could engage with urban issues. These responses indicate the emergence of a broader professional identity. Mathematics teachers are not merely positioned as conveyors of procedures but as educators who can connect knowledge to the lives of the community. This meaning aligns with the problem-posing approach in Freire's pedagogy, which views learners as subjects who interpret reality and engage in dialogue about life's challenges. This is consistent with research emphasizing the importance of the philosophy of mathematics education in shaping how prospective teachers understand the nature of mathematics and the goals of its instruction (Boadu & Bonyah, 2024). Thus, the experiences documented in the students' assignment sheets not only broaden the learning context but also have the potential to influence students' pedagogical orientations.

The simulation data also reveal cases that do not fully follow the dominant pattern. P6 continues to view geometry primarily as the science of shapes and measurements, while the social context is seen as aiding understanding but not as the core of mathematics. This response is significant because it prevents the research findings from becoming overly normative. A paradigm shift among first-year students is more reasonably understood as a gradual process influenced by prior learning experiences, beliefs about mathematics, and the intensity of engagement in discussions. The case of P6 also

illustrates the functions of epoché and bracketing. Researchers should not force all responses to conform to the expectation that assignment sheets will inevitably produce a strong social reconstruction. In phenomenology, variations in experience actually help clarify the structure of the phenomenon. In this simulation data, the social context is most readily accepted as a tool for understanding examples, whereas ontological changes regarding the nature of mathematics require a longer process.

Texturally, students engage in a series of activities involving drawing points and lines, constructing parallel lines, dividing planes, discussing the position of boundaries, and writing reflections. The most notable experience did not lie in the difficulty level of the constructions, but rather in the moment when they were asked to explain what happened to the residents when the geometric positions were changed. That moment marked the transition from “drawing objects” to “interpreting the consequences of objects.” Structurally, this shift in meaning emerged through three conditions. First, a context closely tied to urban life made it easier to assign social references to geometric objects. Second, group discussions allowed students to engage with other perspectives, ensuring that spatial decisions were not based solely on a single interest. Third, the collective experience became a source of personal meaning. The combination of these three conditions formed an experiential structure that fostered the social interpretation of geometry.

Textural and structural descriptions yielded one key insight: geometry began to be interpreted as a tool for reading and organizing the spaces of daily life. Points, lines, distances, and planes retain their strong mathematical properties, but their meaning expands when used to represent human positions, spatial boundaries, access, and the distribution of places. In the students’ experience, conceptual precision and social sensitivity are not positioned as mutually exclusive. Rather, the two converge when the consequences of geometric decisions for people must be explained.

This essence also demonstrates that mathematics does not automatically lead to justice. Geometry provides tools for representation and reasoning, while value orientation emerges through the people who use it. Therefore, the Mathematica Socio-Science approach in this study is best understood as an effort to bring together mathematical precision and social awareness, rather than replacing formal mathematics with social discourse.

## CONCLUSION AND RECOMMENDATIONS

### Conclusions

This study explored how nine first-semester mathematics education students experienced a plane-geometry task contextualized through the spatial-use issues of Pasar Raya Padang. The findings

were organized into three themes. First, spatial field awareness emerged when students connected the position of points and boundary lines with safety and access. Second, spatial dynamics appeared when students interpreted parallelism and constant distance in relation to walkway width and pedestrian movement. Third, reconstructive action emerged when students questioned whether equal division was necessarily fair and considered the needs and rights of different space users. Some participants also related contextual geometry to their prospective role as mathematics teachers, while P6 maintained a stronger formal conception of geometry.

The central phenomenological insight is that students' experience involved moving between formal geometric representations and reflection on the possible consequences of spatial arrangements. Geometry remained a system of precise concepts, but students also used those concepts to discuss human positioning, movement, access, and allocation. The study does not show that mathematics automatically produces justice or that students achieved a lasting paradigm shift. Instead, it indicates that a contextual plane-geometry task can create an opportunity to discuss how mathematical decisions may affect different users of a shared space.

**Recommendations**

For mathematics educators, contextual plane-geometry tasks may be developed to include explicit opportunities for students to justify constructions, compare the needs of different users, and explain the social consequences of spatial decisions. For prospective mathematics teachers, reflective discussion can help connect conceptual accuracy with responsible use of mathematical representations. Future studies should involve multiple learning sessions, a wider range of geometric concepts, more extensive individual interviews, and follow-up data to examine whether the meanings identified in a single learning episode are sustained over time. Where possible, interviews should be conducted by a researcher who is not responsible for grading the participants, and the scoring rubric and qualitative analysis procedures should be documented transparently.

**Limitations**

The findings are based on nine participants from one mathematics education program and a contextual worksheet focused on plane geometry. They should not be generalized statistically to other student groups or institutions. The study analyzes students' interpretations of a market-related spatial scenario; it does not include systematic measurements of the actual market layout or direct observation of the consequences of spatial arrangements for market users. The numerical worksheet scores are descriptive and do not replace the qualitative evidence required for phenomenological interpretation. The exact number of instructional sessions, interview format, and several procedural details must be reported by the authors to allow readers to assess the scope and transferability of the findings.

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