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The Role of Junior High School Students in Group Discussions to Solve Fermi Problems

Wayan Indi Haidar Mufidah[1], Susiswo[2,*], Santi Irawati [3,4]
[1,2,3] Mathematics Departement, Universitas Negeri Malang, Malang
[4] Pusat Gender dan Kependudukan, Universitas Negeri Malang, Malang
*Corresponding Authors: susiswo.fmipa@um.ac.id

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ABSTRACT

This study investigates how junior high school students adopt and shift roles during group discussions while solving Fermi problems, using Positioning Theory as an analytical framework. The study employs a qualitative-descriptive approach with the subjects of eight students of class IX PD-CI MTsN 1 Kediri who were divided into two groups selected using purposive sampling techniques. Data were collected from audio and video recordings of group discussions, which were transcribed and coded for patterns of positioning, negotiation, and interaction, along with students' written responses. The findings reveal that students take on different roles: novices often participate passively, facilitators organize the discussion and encourage participation, while experts contribute key information and guide reasoning. Some groups demonstrated dynamic role shifts throughout the activity, reflecting increased engagement and conceptual understanding, whereas others maintained more static participation patterns, limiting opportunities for collaborative idea exploration. This study uniquely analyzes role shifts among junior high school students through Positioning Theory in the context of Fermi problems. These findings highlight the importance of monitoring and structuring collaborative activities to promote equitable participation. For mathematics educators, understanding positioning patterns can inform instructional strategies, such as role rotation, supporting novice participation, and designing Fermi problems that foster active collaboration.

Keywords: collaborative learning; fermi problems; group discussion; positioning theory; student roles

INTRODUCTION

Mathematics is a subject that holds a crucial role in fostering students' thinking abilities. Mathematics instruction extends beyond the mastery of computational skills; it also directs students to engage in reasoning and to apply learned concepts in real-world situations (Lestari et al., 2025). The implementation of the Merdeka Curriculum represents an effort to promote meaningful and contextual learning that fosters student autonomy. This curriculum is designed to reinforce the Pancasila Student Profile, which emphasizes critical reasoning and collaborative skills in solving real-world problems (Kemendikbudristek, 2022).

A type of task that fosters these competencies is the Fermi problem. Fermi problems are open-ended modeling tasks that do not have a single correct solution but generate multiple plausible answers based on students' assumptions, strategies, and data (Segura & Ferrando, 2023). Solving Fermi problems involves decomposing complex problems into smaller sub-problems and arriving at final solutions through reasonable estimations, after considering each sub-problem carefully (Ärlebäck & Albarracín, 2019). Their open-ended nature encourages diverse ideas and strategies, making student interaction essential for comparing assumptions, negotiating approaches, and critically examining estimations (Brunet-Biarnes & Albarracín, 2024). Group discussions provide an effective platform for such interactions, supporting collaborative thinking and deeper understanding (Gustavsen & Foshaug Vennebo, 2025; Steenkamp & Brink, 2024).

Through group discussions, students can exchange ideas, collaborate, and develop logical reasoning while enhancing positive attitudes toward mathematics (Gustafsson, 2024). They engage not only in identifying correct solutions but also in collaboratively constructing problem-solving strategies (Chang et al., 2017). Students interact with peers and themselves, developing perspectives before and during group engagement (Schindler & Bakker, 2020), observing others' strategies, and sharing problem-solving processes (DeJarnette & González, 2015).

Despite these benefits, group discussions may present challenges such as uncollaborative social dynamics, domination by certain students, and passive participation by others (Campbell & Hodges, 2020). Imbalanced social dynamics can hinder equitable knowledge construction, while suboptimal group composition and size may reduce interaction quality and affect understanding (Radebe & Mushayikwa, 2023). Understanding group interactions is therefore crucial to examine how students assume and enact roles during discussions.

Positioning Theory provides a framework to analyze these interactions, showing how students position themselves and are positioned by peers during collaborative work (DeJarnette & González, 2015). For example, students asking questions position themselves differently from those answering, and positioning reflects students' alignment based on their abilities. In discussions, students may assume roles such as experts, novices, or facilitators, which provides insight into collaboration, communication, and intrapersonal skill development (DeJarnette & González, 2015; Drageset & Ell, 2024; Sari et al., 2021). Prior research has applied Positioning Theory in algebra (DeJarnette & González, 2015), collaborative geometric problem-solving (Firmansyah et al., 2022), relations and functions (Jennah & Subanji, 2024), and role transitions guided by Polya's cognitive principles (Muslim et al., 2024).

Although Positioning Theory has been applied in various mathematical contexts, few studies have explored how junior high school students' roles evolve during group discussions solving Fermi problems. This study fills that gap by identifying and analyzing role dynamics through Positioning Theory. The purpose of this research is to describe patterns of students' roles and the shifts in these roles at each stage of Fermi problem-solving.

RESEARCH METHODS

This study employed a qualitative descriptive approach to investigate how junior high school students adopt and shift roles during group discussions while solving Fermi problems, analyzed using Positioning Theory. Student interactions were categorized into three main roles: expert, facilitator, and novice (DeJarnette & González, 2015; Drageset & Ell, 2024) based on verbal patterns and actions observed during the discussions. The problem-solving steps were adapted from Brunet-Biarnes & Albarracín (2024), comprising six stages: (1)

Understanding the problem; (2) Developing strategies and mathematical modeling; (3) Estimation; (4) Calculation; (5) Validation; and (6) Drawing conclusions.

The study was conducted at MTsN 1 Kediri during the final semester of the 2024–2025 academic year. Participants were selected from class IX PD-CI, which demonstrated above-average academic ability. Eight students were purposively chosen based on recommendations from the mathematics teacher, ensuring that they had adequate communication skills, willingness to collaborate, and active engagement in learning. The participants were divided into two groups of four students each for discussion activities.

Data were collected using multiple instruments: (a) Fermi problem tasks; (b) negotiation coding guidelines (Table 1); (c) positioning coding guidelines (Table 2); and (d) audio-visual recording devices. Each group worked collaboratively on the Fermi problems while being recorded on video. The recordings were transcribed and coded for analysis.

The data analysis involved transcribing the videos, coding the transcripts according to the negotiation guidelines, and categorizing the codes following the positioning guidelines. Finally, students' positioning patterns were analyzed, and conclusions were drawn based on the coded data.

Table 1. Negotiation Guidelines (DeJarnette & González, 2015; Firmansyah et al., 2022)

Code		Positioning	Guidelines
K1	*Primary knowledge*	Providing information	The student makes a statement to convey information
dK1	*Delayed primary knowledge*	Providing stimulus	The student withholds information temporarily to prompt further discussion
rK1	*Repeat* K1	Repeating K1	The student restates the information they previously provided
K2	*Secondary knowledge*	Requesting information	The student asks a question to obtain information
rK2	*Response K1*	Responding to K1	The student responds to the initial information (K1) as a follow-up to K2
A1	*Prior actor*	Performing an action or service	The student performs a task or provides a service for the group
dA1	*Delayed prior actor*	Volunteering	The student offers themselves to perform an action
A2	*Secondary actor*	Requesting an action	The student asks someone else to carry out an action
ch	*Challenge*	Challenging others (Ch)	The student questions a suggestion and requests justification or clarification
rch	*Respond to challenge*	Responding to Ch	The student provides clarification in response to the challenge
Q1	*Question*	Expressing confusion	The student expresses a lack of understanding of the information
P1	*Activation discuss*	Delegating discussion control	The student transfers discussion control to another group member
X1	*Inappropriate*	Providing an irrelevant response	The student gives a response that is not appropriate to the discussion context

Table 2. Positioning Guidelines (DeJarnette & González, 2015; Firmansyah et al., 2022)

Positioning	Guidelines
Expert	The student frequently performs K1 (providing information), occasionally performs K2 (requesting information), frequently performs rK2 (responding to K1), frequently performs dK1 (repeating information), occasionally performs A1 (performing an action), and frequently performs dA1 (repeating an action)
Facilitator	The student frequently performs A2 (delegating discussion control), A1 (performing an action), and P1 (volunteering to take action)
Novice	The student frequently performs K2 (requesting information), X1 (expressing confusion), and Q1 (responding inappropriately)

The coding guidelines were validated by two expert validators, receiving an overall score of 3 out of 4, and were deemed valid. Expert review by a mathematics education researcher further confirmed their alignment with the theoretical framework. Participation was voluntary, with written consent obtained from the students. Student identities were anonymized, and all data were securely stored.

RESULTS AND DISCUSSION

During the implementation, each student group was given the same Fermi problem. The group discussions were recorded and transcribed for analysis based on the Fermi problem-solving steps and students' role criteria according to Positioning Theory. The Fermi problem-solving steps included: understanding the problem, developing strategies and modeling, making estimations, performing calculations, validating results, and drawing conclusions.

Discussion Group 1 – Dynamic Roles

The students' roles in Discussion Group 1 during the Fermi problem-solving process are presented in Table 3.

Table 3. Students' Roles in Group 1 during Fermi Problem-Solving

No	Fermi Problem-Solving Stage	Fermi Problem	The Roles of Students in Group 1			
			SEL1	SDL1	SNP1	SKP1
1.	Understanding the problem	1a	Expert	Facilitator	Novice	Novice
		1b	Expert	Facilitator	Novice	Novice
2.	Developing strategy and model	1a	Expert	Facilitator	Novice	Facilitator
		1b	Expert	Expert	Novice	Expert
3.	Estimations	1a	Expert	Facilitator	Novice	Expert and Facilitator
		1b	Expert	Expert	Novice	Expert and Facilitator
4.	Calculations	1a	Expert	Facilitator	Novice	Facilitator
		1b	Expert	Expert	Novice	Novice
5.	Validation	1a	Expert	Facilitator	Novice	Facilitator
		1b	Expert	Expert	Novice	Facilitator
6.	Conclusions	1a	Expert	Facilitator	Facilitator	Facilitator
		1b	Expert	Expert	Novice	Facilitator

Table 3 shows that SEL1 demonstrated cognitive dominance and contributed actively at every stage of the discussion. SEL1 consistently assumed the primary role of an expert, engaging in understanding the problem, developing strategies and models, making estimations, performing calculations, validating results, and drawing conclusions. SDL1 functioned as a facilitator and occasionally as an expert in solving the Fermi problem, initiating actions such as reading the problem aloud, recording proposed ideas, and assisting with calculations. Interactions during the calculation stage are illustrated in the excerpts presented in Table 4.

Table 4. Excerpts from the Transcript of Discussion Group 1 (a)

Subject	Conversation	Negotiation Code
SDL1	1. *[Writing down numbers on paper]*	A1
	2. *Okay-okay, so what's next if we already have the numbers?*	K2
SEL1	1. *Alright, now we just need to find the volume of the pool and the volume of the ball, then divide*	K1
SDL1	1. *[Calculating the volume of the pool]*	A1
	2. *You take care of the volume of the ball*	A2
SKP1	1. *Okaayyy… [Attempts to calculate the volume of the ball]*	A1

SNP1, as shown in Table 3, exhibited dynamic role shifts during the group discussion. Initially, SNP1 assumed the role of a passive novice, merely listening to explanations from group members and not actively participating. As the discussion progressed, SNP1 developed into a reflective novice, frequently asking questions to build understanding, although they still did not fully grasp the expert's statements, as illustrated in the transcript excerpts in Table 5. Subsequently, SNP1 further assumed the role of an expert by contributing ideas during the calculation stage; however, they eventually reverted to the novice role.

Table 5. Excerpts from the Transcript of Discussion Group 1 (b)

Subject	Conversation	Negotiation Code
SEL1	1. *I think one box is 0.5 meters high, 1 meter long, and 0.5 meters wide*	K1
SNP1	1. *Is a small box really 1 meter? Isn't it less than 1 meter?*	K2
SEL1	1. *Yes, approximately 1 meter. Try to notice — the height of the pool is about the same as the length of the storage box.*	K1
SNP1	1. *ohhh…..*	Q1

Based on Table 3, SKP1 exhibited dynamic role shifts during the group discussion. At the problem-understanding stage, SKP1 acted as a reflective novice, primarily listening to explanations from group members and expressing confusion as a means to build understanding. During the strategy and modeling stage, SKP1 assumed the role of a facilitator in Fermi Problem 1a and became an expert in Problem 1b. During the estimation stage, SKP1 played a dual role as both expert and facilitator—engaging in action K1 by correcting the value of π (3.14) and in action A1 by assisting with the calculation of the sphere's volume, as illustrated in the transcript excerpts presented in Table 6.

Table 6. Excerpts from the Transcript of Discussion Group 1 (c)

Subject	Conversations	Negotiation Code
SKP1	1. *Huh? What was that? 3 point what again?*	rK2
SEL1	1. $3{,}15 \times \frac{4}{3}$	rK1
SKP1	1. *Why 3.15?*	rK2
	2. *It should be 3.14, since that's Pi.*	K1
SEL1	1. *Oh great*	rK2
SDL1	1. *[Trying to calculate* $\frac{4}{3} \times 3{,}14 \times 125$*]*	A1
SKP1	1. *[Trying to help]*	A1

Discussion Group 2 – Static Roles

The roles of students in Discussion Group 2 during the Fermi problem-solving process are presented in Table 7.

Table 7. The Roles of Students in Group 2 in Solving the Fermi Problem

No	Fermi Problem-Solving Stage	Fermi Problem	The Roles of Students in Group 1			
			SML2	SVL2	SCP2	SAP2
1.	Understanding the problem	1a	Expert	Novice	Expert	Novice
		1b	Expert	Novice	Facilitator	Novice
2.	Developing strategy and model	1a	Expert	Novice	Expert	Novice
		1b	Expert	Novice	Expert	Novice
3.	Estimations	1a	Expert	Novice	Expert	Novice
		1b	Expert	Novice	Expert	Novice
4.	Calculations	1a	Expert	Novice	Expert	Novice
		1b	Expert	Novice	Expert	Novice
5.	Validation	1a	Expert	Novice	Expert	Novice
		1b	Expert	Novice	Novice	Novice
6.	Conclusions	1a	Expert	Novice	Facilitator	Novice
		1b	Expert	Novice	Facilitator	Novice

Based on Table 7, SML2 predominantly assumed the role of an expert, both cognitively and socially. SML2 demonstrated a high level of engagement by consistently providing key information and maintaining the expert role throughout all stages of the problem-solving process—from understanding the problem, developing strategies and models, making estimations, performing calculations, validating results, to drawing conclusions. This is illustrated in the transcript excerpts presented in Table 8.

Table 8. Excerpts from the Transcript of Discussion Group 2 (a)

Subject	Conversations	Negotiation Code
SML2	1. *So… the height is 0.6, the length is the same as the width, so it's 2 meters long and 2 meters wide?*	dK1
SCP2	1. *Right*	K1
	2. *That means the balls that can be taken… Are there any full balls in this area?*	K2
SML2	1. *[Counting balls] "1, 2, 3, 4, 5, 6. There are 6 balls. 6 divided by 0.6 equals 0.1, so the diameter of each ball is 10 cm."*	K1
	2. *Is it possible for a ball to be 10 cm in diameter?*	dK1

Based on Table 8, SML2 acted as an expert by performing a K1 shift through presenting a visual observation strategy—namely, counting the number of balls within one unit of height. SML2 then connected this information by dividing the height of the container by the number of balls. SML2 also demonstrated a dK1 shift by delaying the delivery of information.

Based on Table 5, SVL2 assumed the role of a passive novice who did not display active engagement throughout all stages of the problem-solving process. During the group discussion, SVL2 remained mostly silent, did not take initiative, and showed limited understanding of the information. Such behavior reflects the typical passive and restricted participation of novice students in group discussions. SVL2 did suggest an estimate regarding the height of the storage box, but the idea was rejected by SCP2 and SML2, as shown in the transcript excerpts in Table 9.

Table 9. Excerpts from the Transcript of Discussion Group 2 (b)

Subject	Conversations	Negotiation Code
SVL2	1. *This is half of the pool height [while pointing at the storage box height]*	K1
SCP2	1. *No, it's not*	ch
SVL2	1. *There's a lid on top*	rch
SML2	1. *Wait a second… no, it's not right*	ch
	2. *Earlier we said the pool height was 0.6 meters, so the height of two storage boxes would be 0.8*	K1

SCP2 demonstrated dynamic role shifts throughout the discussion process, as shown in Table 7. During the problem-understanding stage for Fermi task 1a, SCP2 acted as an expert by showing active engagement from the beginning. This was evident from the responsive contributions made in reaction to questions posed by other group members. In contrast, during the problem-understanding stage for Fermi task 1b, SCP2 assumed the role of a facilitator by initiating actions without prompts from peers.

During the stages of strategy and model development, estimation, and calculation, SCP2 served as a supporting expert, contributing ideas and clarifications, although not fully dominating the decision-making process. This role performance is illustrated in the transcript excerpts presented in Table 10.

Table 10. Excerpts from the Transcript of Discussion Group 2 (c)

Subject	Conversations	Negotiation Code
SCP2	1. *Huh? Half the width of the box is equal to its height? Wait, that doesn't make sense, does it?*	dK1
SML2	1. *Yes, it does make sense. Half of the box's height is equal to its width.* 2. *So the length is 2, the height is 4, and the width is 8. Multiply all that, and we get 64 balls.*	K1 K1
SCP2	1. *So 2000 was divided by 64.*	K1

During the validation stage, SCP2 acted as a facilitator in Fermi task 1a by keeping the discussion focused and reiterating statements previously expressed by the primary expert student (SML2). In Fermi task 1b, SCP2 assumed the role of a novice by questioning the validity of the obtained answer. In the conclusion stage, SCP2 again served as a facilitator by taking the initiative to write down the final result.

SAP2 consistently acted as a passive novice throughout all stages of the Fermi problem-solving process, as shown in Table 7. From the beginning to the end of the discussion, SAP2 remained mostly silent and did not respond to other group members during the discussion.

Role Shifts of Students in Group Discussions

Students in Discussion Group 1 demonstrated dynamic role shifts throughout the process of solving the Fermi problems, beginning from understanding the problem, developing strategies and mathematical models, estimating, calculating, validating results, and concluding. These transitions from novice, to facilitator, and ultimately to expert indicate increasing engagement and active participation in group problem-solving. The progression of roles suggests meaningful development in students' mathematical reasoning and collaborative involvement. This finding supports DeJarnette & González (2015), who argue that active negotiation and positional shifts create opportunities for students to engage in mathematical reasoning during collaborative problem-solving. Similarly, Muslim et al. (2024) found that role shifts positively influence social dynamics and contribute to the development of critical thinking and problem-solving abilities.

Moreover, communication quality within Group 1 evolved at each discussion stage. Interaction was shaped not only by the discussion process itself but also by the positional identities assumed by students (Drageset & Ell, 2024). This is in line with Mercer (2000), who emphasizes the importance of *interactive talk* as a central medium for co-constructing knowledge through the constructive exchange of ideas. In this study, interactive talk was evident when students responded to peers, corrected misunderstandings, and collaboratively refined ideas to reach shared understanding. Likewise, Littleton & Howe (2010) highlight that collaborative interaction fosters reflective and argumentative thinking, resulting in more meaningful learning experiences.

In contrast, students in Discussion Group 2 predominantly exhibited static roles when solving the Fermi problems. Several students maintained the same role throughout the discussion; for instance, one consistently acted as an expert while another remained in a novice role across all stages. Campbell and Hodges (2020) note that such patterns commonly emerge in groups with dominant-submissive dynamics, where some members remain passive and simply follow more dominant peers. When one or two individuals dominate interaction, opportunities for collaborative idea exploration are significantly reduced. Additionally, Mercer's (2000) theory of social interaction suggests that unbalanced communication and role dominance hinder *interactive talk*, which is essential for shared knowledge construction. Therefore, the static role patterns observed here indicate less optimal social dynamics for achieving collaborative learning goals.

Each role demonstrated distinct interaction characteristics. Expert students showed cognitive leadership and contributed actively across all problem-solving stages. This aligns with DeJarnette & González (2015), who note that expert students are often positioned as primary knowledge sources. In the present study, experts relied on prior knowledge and experience when solving the Fermi problems, consistent with findings by Jennah & Subanji (2024), who observed that experts often justify solutions using their existing understanding. Meanwhile, student facilitators initiated actions without prompting and supported group needs throughout the discussion, managing task distribution and encouraging peer participation (Zhang et al., 2019). Novice students frequently asked questions to construct understanding and accepted group decisions without further justification. This is consistent with Firmansyah et al. (2022), who report that novices tend to follow expert and facilitator reasoning. Some novices also remained silent and occasionally did not respond to peers, aligning with Ridho et al. (2023), who describe beginners as rarely exhibiting collaborative gestures and primarily acting as passive group members.

This study has several limitations, including a small sample size, short observation period, and the focus on a single school context. Future research may explore a larger and more diverse population, examine structured interventions to balance participation, and investigate the long-term effects of role rotation on students' collaborative problem-solving skills.

CONCLUSION

This study reveals distinct patterns in students' role dynamics during collaborative Fermi problem solving. Expert students consistently engaged in knowledge-driven actions and assumed leadership within the discussion, while facilitators actively fostered interaction and supported group coordination. Novice students primarily sought information and clarification, and at times remained passive or silent. Students in Discussion Group 1 exhibited dynamic role shifts throughout the Fermi problem-solving process. These shifts reflect growth in students' engagement and understanding as the collaborative problem-solving progressed. In contrast, the static roles observed in Discussion Group 2 indicate limited participation and dominance by certain students, which restricted opportunities for collaborative idea exploration. These findings highlight the importance of monitoring and structuring collaborative activities to promote equitable participation. For mathematics educators, understanding positioning patterns can inform instructional strategies, such as role rotation, scaffolding novice participation, and designing Fermi problems that encourage active collaboration.

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