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Descriptive Characteristics of Systematic Functional Gestures Used by Pre-Service Earth Science Teachers in Classroom Learning Environments

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Abstract: This study aimed to explore the characteristics and dimensions of of systematic functional gestures employed by pre-service Earth science teachers during instructional sessions. Data were collected from eight students enrolled in a university's Department of Earth Science Education. The data included lesson plans, activity sheets, and recordings of one class session from participants. The analysis, conducted using the systemic functional multimodal discourse analysis framework, categorized gestures into scientific and social functional dimensions. Further subdivision identified meta gestures, analytical gestures, and interrelated gestures. Additionally, pre-service teachers used gestures to explain scientific concepts, concretely represent ideas and facilitate communication during instruction. This study emphasizes the nonverbal strategies used by pre-service Earth science teachers, highlighting the importance of noverbal communication in teachers' professional development and the need for its integration into education. It also establishes a systematic conceptual framework for understanding gestures in the instructional context.

Keywords: Pre-service Earth Science Teachers, Gestures, Systemic Functional Multimodal Discourse Analysis (SFMDA)

1. Introduction

The classroom environment is the most common place for teaching and learning to occur, as well as being a familiar setting for us to experience education during our school years. In this environment, students can acquire specific subject matter knowledge or information and systematic structures provided by the teacher. Recently, teaching and learning have not been limited to traditional areas but have also included the use of new technological tools. In this respect, there is a need to focus on multimodality in the teaching and learning process to facilitate students' communication across various domains. Multimodality refers to the semiotic domain that represents various tools and modes of communication (Kress, 2009). For effective communication, teachers and students use various modes of representation, such as spoken language, posture, movement, gaze, and gestures. These diverse modes can serve as communication tools for the smooth transfer of information between teachers and students. Among these, focusing on the non-verbal aspect, specifically gestures used by instructors, is necessary based on research findings that indicate gestures can enhance the teaching and learning experience (Kasten et al., 2008).

Instructors' use of gestures can enhance learning in the cognitive domain for students within the teaching and learning environment. Previous research reports that various gestures used by students and teachers in diverse subjects such as mathematics, physics, astronomy, geology, music, and language learning can positively impact students' learning of subject matter (Atit et al., 2015; Carlson et al., 2014; Cook et al., 2017; Matsumoto and Dobs, 2017; Padalkar and Ramadas 2011; Simones et al., 2015). In mathematics, when teachers utilize gestures to explain equations and graphs, it can positively affect students' knowledge acquisition. There is also ongoing research emphasizing the importance of participants' gestures in the learning context of specific subjects, such as field geology in Earth science courses (Choi et al., 2020). Thus, teachers' gestures are not limited to mere communication but

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can be approached as a tool for learning subject content, potentially having a positive impact on students' learning. With the recent technological advancements in our society and the emphasis on cultivating digital literacy in the 2022 revised curriculum, there is a shift from focusing solely on traditional educational environments to establishing new systems in classroom environments where teachers and students can diversify their modes of communication through more varied behaviors.

Given the current educational context, it cannot be overstated how crucial the gestures used by teachers in the teaching and learning process are. Contrary to this principle, at the stage of training prospective teachers, there is a deficiency in emphasis and research on the importance of non-verbal contexts, such as gestures used by teachers, amid learning traditional theories and about the school environment in the teaching and learning process. In summary, while emphasizing the importance of the non-verbal aspects of teachers in the teaching and learning process and the multi-dimensionality of communication behaviors between teachers and students, there exists a gap in education and research targeting prospective teachers. From this perspective, this study anticipates helping bridge the gap between education and research by emphasizing the importance of teachers' use of gestures and proposing an empirical approach to instructing this at the stage of training prospective teachers.

The context of subject education and previous research on gestures used by participants (teachers and students) in teaching and learning situations can be categorized into structuring or logically classifying gestures, the relationship between gestures and quantitative reasoning, and research on the non-verbal characteristics of gestures. However, previous studies have shown limitations in reclassifying gestures or exploring their functional features within the context of subject education through the conventional approach of gestures used in cognitive psychology. While some research has been conducted on classifying or reestablishing gestures in contexts like field geology excursions or in teaching and learning strategies for scientific models and modeling (Choi et al., 2023), approaches considering the unique aspects of science education or the educational context of Korea have not been adequately addressed. This study aims to explore the gestures used by prospective teachers within the context of Earth science education in the given situation of the teaching and learning process.

Considering the current educational context, the study applies a systemic functional multimodal discourse analysis method to classify and analyze the technical features of gestures used by prospective teachers. This analysis framework, grounded in Systemic Functional Theory, offers a suitable approach to reinterpret gestures used by prospective teachers within the teaching and learning process, in an educational context, reflecting multimodality. Systemic Functional Theory understands language as a functional system, providing a theory for analyzing language in relation to its function as a tool for communication. This theory will be useful in understanding how language performs functions in interaction and communication among people by analyzing the various functional aspects of language. This study utilizes Systemic Functional Multimodal Discourse Analysis (SFMDA), rooted in Systemic Functional Theory, as an analytical framework for data analysis (Lim, 2021). This framework serves as a tool for detailed analysis of the various communication processes occurring in the teaching and learning process through the multimodality of discourse, especially emphasizing the non-verbal aspects (Lim, 2019). For example, it allows for the creation of a system for gestures used by prospective teachers or detailed description of their meaning, interpreting the non-verbal aspects and the meaning of gestures in interaction and communication in technical and functional domains formally. Previous research has classified the gestures used by teachers in classrooms, focusing on life science and language teachers (Liu et al., 2022). However, these classifications did not reflect the context of science education or the teaching and learning process in Earth science education.

The purpose of this study is to explore the gesture classification system and analyze the functional features

through Systemic Functional Multimodal Discourse Analysis in the context of teaching and learning in Earth science. Analyzing gestures used by prospective teachers in the teaching and learning process will allow for an in-depth exploration of the various interactions occurring in this process from the perspective of multimodality, focusing particularly on the non-verbal aspects. Ultimately, exploring the gestures used by prospective teachers in teaching and learning situations is expected to help qualitatively understand their teaching and learning process in the context of Earth science education.

2. Research Questions

Exploring the gestures used by prospective teachers in a traditional classroom environment can ultimately be considered a fundamental and crucial step towards enhancing the pedagogical professionalism of prospective teachers' lessons. The gestures used by prospective teachers can be diversely utilized in explaining scientific concepts or conveying necessary information for communication with others in teaching and learning situations, from a multimodal perspective. Therefore, a deep analysis of the gestures used by prospective teachers in classroom situations will be conducted to analyze the embedded meanings. For this purpose, the following research question has been formulated.

1. What are the systematic aspects of the classification of gestures used by prospective pre-service Earth science teachers in the teaching and learning process?

2. What are the functional characteristics of gestures used by prospective pre-service Earth science teachers in the teaching and learning process?

3. Theoretical Background

3.1. Theory of Multiple Representation (TMR) for Gestures

The integration of gestures within the Theory of Multiple Representations (TMR) transcends being merely an instructional tool in science education and it is an essential component for a holistic educational methodology (Treagust and Tsui, 2013; Won et al., 2014). Gestures, functioning as a pivotal non-verbal mode of communication, offer distinct advantages in elucidating scientific concepts that are inherently abstract and challenging to communicate solely through verbal means (Choi et al., 2023). The theoretical foundation for analyzing gestures within TMR underestimates the learning process as inherently multidimensional, emphasizing the crucial role of employing diverse forms of communication to foster comprehension (Srivastava and Ramadas, 2013).

Gestures encapsulate a type of embodied knowledge, providing both a physical and visual representation of concepts that effectively bridge the divide between abstract theories and tangible understanding (Pouw et al., 2020). This concept is in harmony with cognitive theories advocating that learning reaches its peak efficacy when it engages multiple sensory channels (Barsalou, 1999). Within this framework, gestures are instrumental by activating the visual-spatial channel, thereby complementing the auditory-verbal channel engaged through spoken explanations (Alibali and Nathan, 2012; Gibbs, 2006; Hostetter and Alibali, 2010).

Incorporating gestures into the learning experience enriches it significantly, such as using analogy (Goldin-Meadow and Beilock, 2010; Gilbert and Justi, 2016). This approach posits that information processed through both verbal and non-verbal channels has a higher likelihood of being retained and comprehended. Consequently, gestures are not merely auxiliary; they are integral to creating a memory trace that enhances the recall and understanding of complex information (Liu et al., 2022).

The analysis of gestures also illuminates the importance of catering to the diverse learning styles and preferences present within the classroom (Roth, 2001). By offering an alternate mode of representation, gestures provide a unique entry point for students who may find traditional forms of instruction, such as pictures, diagrams, or verbal explanations, challenging (Choi et al., 2020; Treagust and Tsui, 2013). Moreover,

delving into gestures within the framework of TMR reveals the implicit methods through which knowledge is communicated and comprehended in science education. An examination of how gestures contribute to the construction of meaning allows educators to glean insights into the cognitive processes underpinning learning (Liu et al., 2022). This understanding can inform the development of more effective teaching strategies that are attuned to the natural ways in which students engage with and internalize scientific concepts.

The exploration of gestures within the context of the Theory of Multiple Representations highlights their critical role not only as an educational tool but as a foundational element of effective science education. The analysis of gestures underscores the significance of a multimodal approach that accommodates diverse cognitive processes and learning styles, positioning gestures as a vital component in the endeavor to provide an inclusive, engaging, and comprehensive science education experience.

3.2. Gestures in Teaching and Learning Instruction

The theoretical background of the importance of gestures in teaching and learning situations spans multiple dimensions of human cognition, communication, and pedagogy. Gestures, the expressive movements of the body or limbs, play a crucial role in enhancing the effectiveness of teaching and facilitating learning (Goldin-Meadow et al., 2001; Sepp, 2019).

Gestures serve as a powerful tool for conveying abstract concepts and complex information in a more tangible and comprehensible manner (Agostinho et al., 2015). Teachers' gestures can help explain concrete experiences, abstract knowledge, providing students with a visual dimension of understanding that complements verbal explanations (Cook et al., 2013). Gestures enrich the interaction between teachers and students, fostering a more engaging and interactive learning environment (Alibali et al., 2014; Atit et al., 2014). Previous research posits that gestures and speech are intertwined, forming a unified system of communication that enhances the clarity and effectiveness of the message being conveyed. In classrooms, gestures can emphasize key points, illustrate processes, and signal transitions in the discourse, aiding students' comprehension, and retention of the material (Wagner et al., 2014).

The use of gestures in teaching aligns with the multimodal theory of communication, which asserts that people communicate and understand through multiple modes, including verbal, visual, and gestures (Bezemer and Kress, 2014). In the classroom, the integration of gestures with speech and visual aids creates a rich, multimodal learning environment that caters to diverse learning styles and preferences (Taylor, 2014). This multimodal approach not only reinforces the learning content but also fosters a more inclusive and accessible educational experience.

The theoretical and empirical foundations of the importance of gestures in teaching and learning are vast and multifaceted (Rollinde, 2019). Gestures enrich the communicative repertoire of teachers, enabling them to convey abstract concepts more concretely, emphasize key information, and engage with students in a more interactive and multimodal manner (Alibali and Nathan, 2012; Singer et al., 2008). Gestures emerge as a vital pedagogical tool that enhances the effectiveness of instruction and facilitates deeper understanding and retention of knowledge. As such, integrating gestures into teaching practices is not only beneficial but essential for fostering effective learning environments that accommodate the diverse needs and preferences of students (Hostetter and Skirving 2011; Pi et al., 2019).

3.3. Systemic Functional Multimodal Discourse Analysis for Gestures

Systemic Functional Multimodal Discourse Analysis (SFMDA) provides a sophisticated lens through which the significance of gestures in the educational arena can be fully appreciated, particularly when considering the ideational, interpersonal, and textual meta-functions these non-verbal cues embody (Lim, 2020). By delving into the intricacies of how gestures facilitate teaching and learning, it becomes evident

how they transcend mere physical movements to become pivotal components of educational communication and understanding.

At the core of conveying and constructing knowledge within the classroom is the ideational meta-function of gestures. These dynamic visual aids serve as bridges between abstract concepts and tangible understanding, transforming the intangible into visually and experientially comprehensible forms. Previous research illuminates how teachers, using spatial gestures, can demystify complex ideas, enriching students' conceptual grasp (Goldin-Meadow, 2009). This aspect underscores the ability of gestures to make abstract notions not only visible but also accessible, thus enhancing the educational process by grounding theoretical concepts in the physical realm.

Equally vital is the interpersonal meta-function of gestures, which underscores their role in shaping the emotional and relational dynamics of the classroom. Gestures emerge as silent yet profound communicators of encouragement, clarification, and discipline, directly influencing the learning environment's affective quality. The strategic use of gestures can significantly impact student engagement and motivation, fostering a classroom atmosphere that is not only conducive to learning but also supportive of positive teacher-student interactions (Goodwyn et al., 2000). This dimension of gestures highlights their capacity to navigate the social landscape of the classroom, subtly guiding emotional and behavioral norms.

Furthermore, the textual meta-function of gestures reveals their contribution to the structural and organizational aspects of classroom discourse (Lim, 2019). Gestures are instrumental in weaving coherence into the fabric of educational communication, serving as non-verbal markers that highlight crucial information, delineate topic boundaries, and underscore key transitions. It shed light on how these gestural cues aid in the navigation of instructional narratives, thereby bolstering students' understanding and retention of the material presented (Bezemer and Jewitt, 2010). This functionality not only enriches the communicative efficacy of teaching but also enhances the learner's ability to follow and internalize the educational journey.

In synthesizing the roles encompassed by the ideational, interpersonal, and textual meta-functions of gestures within educational settings, it becomes clear that gestures are not ancillary but rather integralto the pedagogical process. They provide a multimodal scaffold that supports the transmission of knowledge, the cultivation of positive learning environments, and the organization of content in ways that are inherently aligned with the cognitive and social dynamics of learning. Through the lens of SFMDA, the depth and breadth of gestures' contributions to education emerge, highlighting their indispensable role in facilitating a holistic and effective learning experience.

In this study, the gestures used by pre-service teachers during the teaching and learning process are analyzed by adopting the definitions provided by Martinec (2000, 2001, 2004) (Fig. 1) and the parameters proposed by Lim (2019) (Table 1).

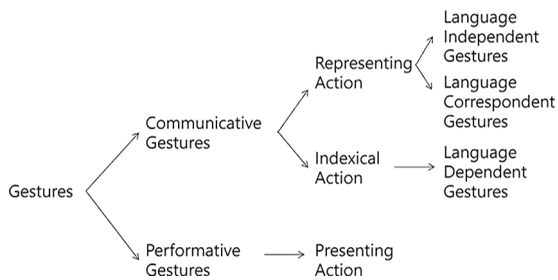


Fig 1. Categories of gesture proposed by Martinec (2000, 2001, 2004)

Table 1. Lim's (2019) parameter of gestures

Category	Parameters
Gestures	· Directionality of gesture (formal) · Description of hand (formal) · Hands level (formal) · Use of hand (formal) · Contact with object (formal) · Types of action (Presenting, Representing, Indexical) · Processes in presenting action · Representing entity · Indexical representation · Attitude (Representing and Indexical Action) · Graduation (Representing and Indexical Action) · Engagement (Representing and Indexical Action) · Specificity (Representing and Indexical Action) · Beat (Representing and Indexical Action)

4. Research Method

4.1. Research Procedures

The research procedure and selection of participants were conducted in five stages as follows. First, a review of the literature and analysis of previous studies related to the research topic were carried out.

Second, convenience sampling was conducted to recruit participants. Consent was sought from prospective Earth science teachers currently enrolled in the Department of Earth Science Education at non-capital region colleges of education.

Third, a lesson plan covering one class period (45 minutes) considering the Earth science teaching and learning process was developed. Based on the lesson plan, a teaching and learning program corresponding to one class period was developed, reconstituting the "Earth Science" unit for second-year middle and high school students according to the Korean 2015 revised curriculum. This process allowed the prospective teachers to reconfigure the teaching and learning program, showcasing their professional expertise based on the existing science curriculum.

Fourth, data collection was conducted among prospective teachers studying in the Department of Earth Science Education at A University. Data collection involved video-audio recording the classroom teaching environment as the prospective teachers conducted lessons based on the developed teaching and learning program. Lesson plans written by the prospective teachers and teaching materials and documents used in the teaching and learning program were collected.

Fifth, the video-recorded lessons conducted by the prospective teachers were analyzed using the SFMDA framework. The analysis was initially carried out by the author, and the results were shared with experts (one Ph.D. in Earth Science Education and one high school Earth Science teacher) to enhance the validity of the data analysis through further discussion. Based on the analyzed data by the research team, the results and conclusions were drawn.

4.2. Research Participants

This study examines the cases (episodes) of three research participants, who will be referred to by the pseudonyms Da-won (and Da-jin), Jin-su, and Min-ju for confidentiality purposes. The participants are among nine prospective Earth science teachers currently enrolled at A College of Education, located in a non-capital region, specializing in Earth Science Education. The research participants have taken courses in earth science education and teaching theory, as well as major courses in geology, oceanography, meteorology, and astronomy.It is important to note that personal information of the research participants is considered confidential and is protected under research ethics. The participants were randomly divided into three groups (Group A, Group B, and Group C), comprising five females and three males.

4.3. Data Collection and Analysis

The research participants prepared a variety of written materials, such as teaching materials, experimental materials, and lesson plans, which corresponded to each lesson topic, in addition to recording video and audio of the lesson performances.

In the process of data collection, the gathering of video footage from pre-service teachers serves as a critical methodological approach (Knoblauch, 2012). This method is particularly suitable for analyzing the gestures employed by pre-service teachers during the teaching and learning process. By capturing the nuances of their physical expressions and movements, researchers can gain deeper insights into the pedagogical strategies and classroom dynamics. Video footage provides a rich, contextual dataset that allows for a detailed examination of non-verbal communication cues and their role in effective teaching. Moreover, this approach facilitates a comprehensive understanding of how gestures can enhance the clarity and impact of instructional messages. Through systematic analysis of these visual records, patterns and types of gestures that contribute to more engaging and effective

teaching methodologies can be identified. Thus, the collection of video footage emerges as a potent tool in the study of pre-service teachers' instructional behaviors, offering valuable perspectives on the integration of gestural communication in science education (Streeck, 2021).

The first research question explores the systematic aspects of the classification system of gestures used by the prospective teachers, utilizing the classification system proposed by Martinec (2000, 2001, 2004) on the Table 1. The coding criteria for classifying gestures were based on the research classification criteria by Lim (2019) on the Fig. 1, which is employing Lim's (2019) gesture coding as an analytical tool for analyzing the gestures used. That is, by utilizing the classification criteria proposed by Martinec (2000, 2001, 2004) along with Lim's (2019) parameter of gestures, this study explored the systematic aspects of gestures suitable for this research inductively.

The second research question explores the functional characteristics of gestures used by pre-service teachers through a multimodal transcription method, describing verbal language, gestures, and contextual situations (Bezemer and Mavers, 2011). This process involves analyzing the functional characteristics of gestures used by students within a multimodal context, following a diachronic analysis method inductively in this research (Radford and Sabena, 2015).

Third, an analysis of the gestures used by prospective teachers in each lesson demonstration episode was conducted, focusing on the functional and roles of the gestures in a systematic classification. Then, the author enhanced the reliability of the analysis by sharing the videos with the research participants and conducting member checking regarding the use of gestures and their purposes.

5. Results

5.1. Exploration of the systematic aspects of gestures

This study explores a new systematic classification of gestures suitable for the context of Earth science education, using the gesture parameters (Lim, 2019) and the classification by Martinec (2000, 2001, 2004) as lenses. It considers the movement of hands as a criterion for classifying gestures, searching within the context of earth science education rather than through a linguistic approach, and analyzes the pedagogical meanings of gestures. For this purpose, it qualitatively analyzes which gestures are used by pre-service secondary Earth science teachers in three lesson episodes, and what those gestures mean.

Table 2 is a result of research question 1 and a summary of the identified gestures. First, the movement was defined from the existing parameters and gesture classifications by Lim (2019) and Martinec (2000, 2001, 2004), then the gestures were named by classifying them into gestures description and examples, and newly identified gestures and dimensions. Following this, examples of the named gestures from each of the three episodes were described.

Episode 1: Understand the reason why Foucault's pendulum movement can prove Earth's rotation by Da-won and Da-Jin

Table 2. Examples of Identified gestures

Parameter and Categories of gestures	Gestures Description and Examples	Identified Gestures	Dimension
Indexical Action - Language Dependent Gestures	The act of depicting the motion of a simple pendulum and accompanying it with spoken language over time.	Meta-gestures	Scientific Functional Gestures
Presenting Action	The movement of a teacher expressing phenomena for representation such as trade winds and the movement of surface seawater, representing the El Niño phenomenon.	Analytical gestures	
Representing Action - Language Independent Gestures	The act of an instructor looking for a presenter to draw the phases of the moon according to the relative positions of the sun, Earth, and moon (raising their hand).	Interrelated-gestures	Social Functional Gestures

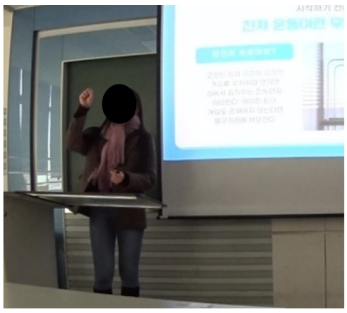


Fig. 2. Meta gesture

Fig. 3. Analytical gesture

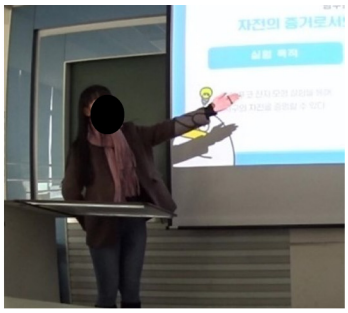


Fig. 4. Interrelated gesture

The first episode features this class, which uses pendulum motion to explain Earth's rotation. The learning objective was to understand why Foucault's pendulum movement can prove Earth's rotation. Pre-service teacher covered the experimental and conceptual explanations of Foucault's pendulum to demonstrate this phenomenon. This episode explores the systematic gestures used by pre-service teacher, categorized a new in this research's context, considering the limitation that such gestures were not previously explored in the context of Earth science education.

Pre-service teacher's systematic gestures can be broadly divided into two dimensions: scientific and social functions and are further detailed into three types: meta gestures, analytical gestures, and relational gestures. Meta gestures represent how pendulum motion changes over time, especially when discussing pendulum motion and Earth's rotation at different latitudes, utilized by instructors. For instance, at high latitudes, the teacher's gestures can actively represent Earth's axis of rotation, Earth's rotation, and the movement of Foucault's pendulum over time (Fig. 2).

Analytical gestures express the sub-movements constituting pendulum motion, such as the point mass and its position in three-dimensional space, and the perpendicular plane between the point mass and its position. This gesture illustrates the fixed point and the pendulum's position, depicting the components constituting simple pendulum motion. The conceptual breakdown of the pendulum enables visual representation of the relationship between the pendulum's swing plane and Earth's rotation. Specifically, a Pre-service teacher's hand, symbolizing both the pendulum and the moving plane, can represent the angle between the pendulum's fixed point and its weight, thereby revealing the continuous movement of the pendulum and Earth's rotation (Fig. 3).

Interrelated gestures are movements by instructors aiming for social functionality during class participation or question and answer (Q & A) sessions, such as raising the palm to point to the presenter (Fig. 4), facilitating communication between participants accompanied by verbal language.

Episode 2: Understanding of El Niño and La Niñaby Jin-su

In this episode, the lesson revolves around explaining El Niño and La Niña, showcasing how instructors utilize gestures for teaching and learning processes. For instance, meta gestures are seen when instructors express the direction of wind or the flow of ocean waters over time (Fig. 5). This includes movements depicting water flowing from east to west or vice versa, as well as vertical movements such as upwelling or sinking of water. In other words, the movement of water is not just articulated through verbal language but also demonstrated alongside teaching materials to reveal the vertical or horizontal movement of water, expressing the flow of water as a movement over time.

Second, analytical gestures are observed when explaining the normal state of the Pacific Ocean, and the conditions during El Niño and La Niña, detailing the flow of ocean water, temperature, winds, and other

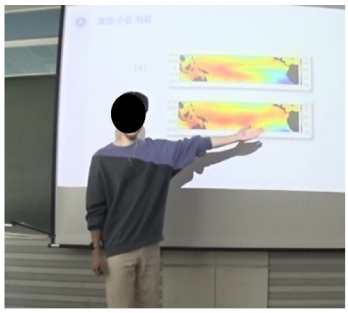


Fig. 5. Meta gesture

Fig. 6. Analytical gesture

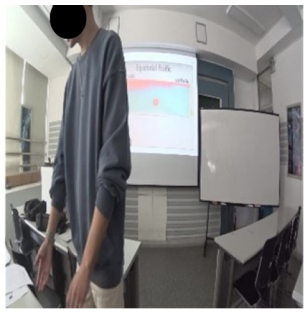


Fig. 7. Interrelated gesture

components. For example, the instructor represented the strengthening of trade winds, the movement of surface water, and the upwelling of cold water during La Niña (Fig. 6). Here, the instructor symbolized the upwelling of cold water to show that as trade winds strengthen and water moves, the empty space is filled by the upwelling of cold seawater.

Third, interrelated gestures are seen in interactions between the instructor and participants during educational activities and processes. For example, by pointing instructor hands, the instructor facilitates communication with the participants. In this scene, as participants continue to observe and record observations, the instructor uses the gesture of pointing hands to ensure smooth participation and convey mutual understanding between them and the participants (Fig. 7).

Episode 3: Understanding of Phase Changes of the Moon by Min-ju

The third episode is a lesson demonstration that focuses on the learning objective of being able to explain the phase changes of the moon. This episode explores the phase changes of the moon over time, following a previous lesson that dealt with the Earth's rotation and revolution.

In this episode, the meta gesture appeared when expressing the physical passage of time in conducting an analogical experiment through actual Styrofoam balls, showcasing the empirical aspect that the moon's phase, its shape, changes day by day over time. In this scene, the pre-service teacher explained the analogical experiment on the screen, utilizing a Styrofoam ball. One of the scenes involved lifting the Styrofoam ball high and moving it in place to guide the observation of the moon's bright and dark parts. A pre-service teacher indicated the appearance of the Earth's moon and expressed the changes in the moon's phases over time by pointing her hand (Fig. 8). Additionally, the changes in the moon's phases depending on its position were approached from the perspective of an Earth observer.

Analytical gestures could be seen when expressing the components of the concept of the moon's phase changes in more detail. For example, this gesture could be seen when learners, becoming Earth observers, observed the moon's phase changes depending on its position and confirmed that the moon's phases differ at each position (Fig. 9). This scene, which is Fig. 9, involved the instructor and learners checking the moon's phases through a Styrofoam ball and drawing out the results of how the moon's phases differ at each position, denoting or illustrating that the moon's phases are different through movement.

Interrelated gestures were observed in the interaction process between the instructor and learners. For example, regarding the topic of the moon's phase changes, learners individually predicted how the moon's phases would change over time and recorded it. Then, through an experiment on the moon's phase changes, the results could be confirmed. In the process of asking and answering whether the predictions matched the experimental results, the instructor encouraged students whose predictions did not match the results to raise their hands (Fig. 10), adding movement by

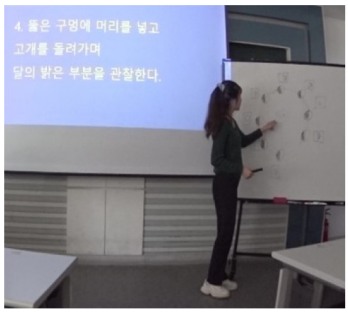


Fig. 8. Meta gesture

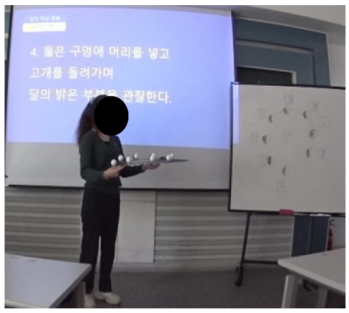


Fig. 9. Analytical gesture

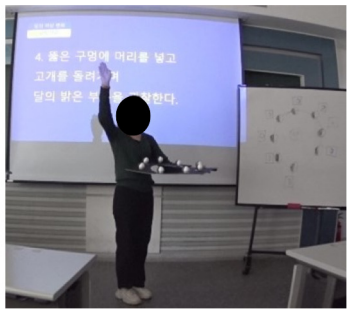


Fig. 10. Interrelated gesture

raising their own hand to respond to the students. This gesture, lifting the hand, was accompanied by spoken language, and even without spoken language, it was a movement that allowed for interpretation of the situation. Relational gestures appeared in the communication process where the instructor raised their hand to compare students' predictions with the experimental results.

5.2. Exploring the functional characteristics of gestures

Episode 1: Understand the reason why Foucault's pendulum movement can prove Earth's rotation by Da-won and Da-Jin

This first episode concerns the motion of Foucault's pendulum. In this episode, various instances of pre-service teachers functionally utilizing gestures to connect scientific concepts can be observed. Specifically, one scene was analyzed to illustrate how a pre-service teacher's gestures exhibited patterns for connecting scientific concepts. For instance, Table 3 depicts a meta-gesture observed from a pre-service teacher. This meta gesture was used when explaining why Foucault's pendulum exhibits linear movements—either left-right or up-down—over time at the equator. The pre-service teacher predicted and illustrated the movement of Foucault's pendulum over time at the equator, relating this movement to scientific concepts. Specifically, when explaining why Foucault's pendulum exhibits linear movement—either left-right or up-down—at the poles, the pre-service teacher illustrated the pendulum's movement from the perspective of an observer situated at the equator. Table 3 sequentially describes the contextual explanation of this situation, the gesture

Table 3. Multimodal transcription for functional characteristics gestures to meta gesture in Episode 1

Contextual Description	Gesture: Meta gesture	Pre-service teacher spoken language	Gesture Description	Gesture Function
The Foucault pendulum exhibits different movements at the poles, mid-latitudes, and the equator. This phenomenon occurs due to varying factors. Specifically, at the equator, it shows linear movement. During the explanation process, while presenting a PPT that illustrates this linear movement at the equator, one can observe the actions of a pre-service teacher.		To understand why the Foucault pendulum appears to move in a straight line at the equator, imagine the pendulum (a rod) swinging. If you oscillate it and then rotate counterclockwise around your head, the pendulum continues to oscillate in place. From your perspective, the pendulum is oscillating, but you only see it moving up and down or side to side in a straight line.	In this scene, the pre-service teacher's gestures can be observed by using the equatorial region as an example. Consider the teacher's head as the Earth's axis and the teacher's gaze as the equator. The teacher rotates counterclockwise, demonstrating the movement over time with their gaze and the rod. This clearly illustrates how the Foucault pendulum at the equator shows a straight-line movement.	The pre-service teacher's gestures visually represent the Foucault pendulum's movement at the equator as a straight-line motion over time, demonstrating the connection to the scientific concept.

scene, spoken language, gesture description, and gesture function.

Episode 2: Understanding of El Niño and La Niña by Jin-su

This episode is about El Niño and La Niña. In this episode, we observe a pre-service teacher's use of analytical gestures to concretely represent ideas. The pre-service teacher utilized numerous gestures while explaining the phenomena of El Niño and La Niña, with a particular focus on analytical gestures in this episode. For instance, Table 4 illustrates one example of an analytical gesture used by the pre-service teacher during the lesson. This analytical gesture is observed when comparing El Niño to normal conditions, explaining the changes in wind and sea movement. The instructor concretely explained this phenomenon by visually depicting the trade winds blowing across the Pacific compared to normal conditions. The pre-service teacher used their hands and arms to visually represent the weakening of the trade winds and the subsequent reduction in upwelling of sea water compared to normal conditions. Such gestures help concretely represent the teacher's ideas and assist in visually explaining natural phenomena. Table 4 sequentially describes the contextual situation, the gesture scene, verbal language, gesture explanation, and the function of the gesture in this context.

Through these analytical gestures, the pre-service teacher concretely represented the El Niño phenomenon. The teacher used their hands and arms to visually depict the horizontal and vertical movements of trade winds and seawater, adding a visual dimension to the explanation of scientific concepts. Particularly, the teacher posed questions to the learners, integrating gestures with verbal language for a multidimensional representation. For example, by asking, "What happens when the equatorial trade winds weaken, unlike normal conditions?" the teacher encouraged active participation from the students.

If the pre-service teacher not only used gestures but also asked questions and facilitated subsequent interactions, the concepts of El Niño and La Niña could be explained in more detail through the combined use of gestures, verbal language, and interactions between the teacher and learners. In such interactions, the teacher could adjust or add gestures in response to students' answers, making the depiction of wind and water movements or height changes clearer. Ultimately, the pre-service teacher's analytical gestures served as a tool to represent natural phenomena in detail to explain the El Niño phenomenon. This use of gestures can effectively translate the teacher's scientific knowledge and ideas into concrete representations.

Episode 3: Understanding of Phase Changes of the Moon by Min-ju

This episode described an example of using interrelated

Table 4. Multimodal transcription for functional characteristics gestures to Analytical gesture in Episode 2

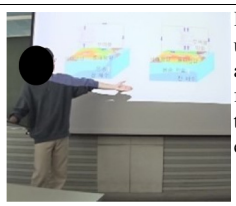
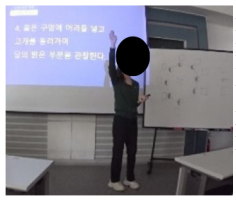
Contextual Description	Gesture: Analytical gesture	Pre-service teacher spoken language	Gesture Description	Gesture Function
The pre-service teacher is explaining the conditions during an El Niño event compared to normal conditions. The objective is to sequentially outline the process through which El Niño develops and ultimately explain why this phenomenon occurs. The pre-service teacher uses a PowerPoint presentation to visually depict normal conditions and those during El Niño.		If the trade winds weaken, upwelling also weakens, allowing the warm water from the western Pacific to move toward the eastern Pacific. Then,	In this scene, the teacher's gesture involves moving one hand from top to bottom. This gesture visually represents the weakened upwelling by raising the hand only slightly instead of raising it high, indicating the reduced intensity of the upwelling.	The pre-service teacher's gesture represented the process of reduced upwelling compared to normal conditions. By demonstrating the weakening of the Pacific trade winds and upwelling compared to normal conditions, the gesture concretely illustrated the natural phenomena observed during an El Niño event.

Table 5. Multimodal transcription for functional characteristics gestures to Interrelated gesture in Episode 3

Contextual Description	Gesture: Interrelated gesture	Pre-service teacher spoken language	Gesture Description	Gesture Function
This describes the process of interaction between the instructor and learners while explaining the phases of the Moon. The pre-service teacher uses gestures in the scene where they are recruiting participants for the Moon phase observation experiment.		Alright, let's learn together how the phases of the Moon change! First, we will recruit one student to participate in the Moon phase observation experiment on a first-come, first-served basis.	The pre-service teacher makes eye contact with all the learners and raises their hand high to find a student to participate in the Moon phase observation experiment.	The pre-service teacher's gesture is intended to capture the students' attention and recruit a participant for the Moon phase observation experiment. This gesture facilitates interaction with the students and encourages their active participation in the learning process.

gestures in the interaction between the instructor and learners during the explanation of the phases of the Moon. Interrelated gestures are used to eliminate unnecessary content or to facilitate communication. Pre-service teacher utilized interrelated gestures while explaining the phases of the Moon through interactions with the students. Table 5 details the contextual situation, gesture scene, verbal language, gesture description, and gesture function in this context.

The pre-service teacher used relational gestures to recruit participants for the Moon phase change experiment and to facilitate interaction with the students. By using these interrelated gestures, the pre-service teacher captured the students' attention and encouraged their participation in the Moon phase change experiment. The act of raising a hand, as interrelated gestures, can effectively promote functional communication within our socio-cultural context and engage learners in the learning process.

6. Conclusions

This study analyzed the gestures used by pre-service earth science teachers within teaching and learning situations through three episodes, employing SFMDA to discern what gestures were used and their meanings. The approach aimed to understand the gestures employed by pre-service teachers during the teaching process, providing foundational data for enhancing the pedagogical expertise of future teachers. Especially, this research pursued to enrich the qualitative aspects of teaching and learning situations by recognizing that gestures could express individual cognitive states or inherent concepts, offering educational implications for the cultivation of teacher professionalism beyond merely considering verbal language.

Firstly, the findings emphasized the significance of utilizing non-verbal aspects, such as gestures, for the enhancement of professional competencies among pre-service earth science teachers. Although many educational programs aim to cultivate teacher professionalism among pre-service earth science teachers, the non-verbal aspects like gestures tend to be under-emphasized. This study highlighted the systematic classification of gestures necessary in teaching and learning situations by analyzing pre-service teachers' gestures, exploring both the categorization and functional aspects of these gestures. It suggested that education emphasizing non-verbal aspects should accompany the emphasis on gestures as one of the tools for pre-service teachers to smoothly conduct their classes. The use of appropriately timed gestures emphasizing non-verbal functional aspects by pre-service teachers is expected to positively influence active interactions with students, explanation of scientific concepts, concretization of abstract meanings, and smooth communication in teaching and learning situations.

The second point is that these research findings can contribute to the expansion of academic research in the field of geoscience education and to the qualitative

growth of gesture-related studies. Previous studies have primarily utilized gestures from a life-history perspective within the fields of developmental and cognitive psychology. Recently, in the geoscience education, gestures have been explored in interpretative approaches linked to field geological excursions and in certain teaching and learning processes. Additionally, this study extended its focus to various areas of the geoscience teaching and learning process, examining the patterns and functional aspects of gestures within a classification framework. This allowed for an expanded interpretation of the significance of gestures in the teaching and learning process. In other words, the study interpreted the instructor's gestures within the teaching and learning process based on a linguistic framework.

7. Implications and Discussion

Drawing upon the findings delineated within this investigation, the subsequent discourse articulates recommendations for future research and discussion points. Initially, this inquiry delved into the myriad gestures employed by pre-service teachers within the confines of a conventional classroom setting. It is posited that additional research focusing on pre-service and in-service educators, particularly concerning the utilization of gestures in pedagogical contexts, is imperative. Such studies are envisaged to underscore the indispensability of educational initiatives aimed at strategizing pedagogical approaches and fostering professional development among pre-service teachers.

Moreover, the interpretation of the extensive and multifaceted use of gestures by instructors during the pedagogical process cannot be unambiguously perceived as beneficial. This necessitates a nuanced examination of gestures tailored to specific educational scenarios and contexts, aiming to elucidate the relationships or causal links between instructors' gestures and profound learning outcomes among students. The bidirectional nature of such gestures underscores the potential for further exploration into their role within the dynamics of instructor-student and student-student interactions, thereby enriching the interpretive framework of the teaching-learning paradigm in Earth Science education.

This study explored the systematic classification gestures used by pre-service earth science teachers during the teaching and learning process. While research on gestures has long been conducted within traditional academic domains such as developmental psychology, focusing on contextual studies of human development, recent research has been exploring gestures within the context of language education and subject teaching, emphasizing the non-verbal domain. However, this research, based on three episodes and analyzing the gestures used by pre-service earth science teachers in covering some earth science content, has limitations in generalizing to typical teaching and learning situations in earth science education.

While preceding scholarship has predominantly concentrated on geology within the Earth Science domain, with numerous studies conducted on a global scale, these have often been restricted to learning environments, such as field trips in geology. It is anticipated that research integrating a consideration of the specific pedagogical settings, instructional models, or the socio-cultural and educational contexts of the teaching-learning process will facilitate a deeper analysis and interpretation of gestures deployed by educators and learners. The incorporation of non-verbal contexts alongside verbal language in lesson analysis is projected to enhance the comprehensiveness of the educational experience from both educators' and students' perspectives.

Lastly, it is proposed that there is a need for an in-depth analysis of the meaning of gestures used by instructors from the perspective of students' academic achievements and other learning outcomes. Even if it is concluded that the gestures of instructors have scientific and social significance, the academic importance should not merely be limited to the standpoint of the instructors. Rather, a comprehensive analysis should be conducted on whether these gestures positively influence students' academic performance in the future. It is anticipated that if empirical follow-up studies are conducted, they could enrich the understanding of the

significance of instructors' gestures.

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