

Examining Middle School Students' Gestures on Geological Field Trips

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Abstract

The purpose of this study was to examine middle school students' gestures during a geological field trip. Previous research on gestures has focused on understanding human development and exploring students' gestures can be helpful in improving understanding of students' communication in learning environments. In this study, middle school students from a gifted education center engaged in fieldwork along the Hantan-River to learn about and explain river formation processes. Using hermeneutics to interpret meaning from student gestures, researchers identified three types of frequently used gestures: deictic, imageable, and depictive, which served either a social communication purpose (explaining, asking, insisting, and giving evidence) or science communication purposes (visualization and temporal or spatial). Researchers offer implications about the role of gestures for helping novice learners communicate geoscience content and about the potential for gestures to be used by educators as an instructional resource for learners.

Keywords

gestures – geological field trip – geoscience education – hermeneutics framework

1 Introduction

One of the most important goals of science education is to develop scientific literacy (NRC, 1996). Scientific literacy is defined as the ability to engage with science-related issues and with the ideas of science as reflective citizens (OECD, 2013). In order to enhance scientific literacy, it is necessary to encourage K-12 students, who will in the future participate in decision-making processes as democratic citizens, to explain phenomena, develop creativity, and think critically. Recently, Korea's local governments have been making efforts to utilize the geological features of each region to help with tourism and economic efforts, including the 2015 certification of the Hantan-River National Geopark (Environmental Agency No. 2015-63) and the 2018 promotion of the Mudeung Mountain National Geopark in Gwangju. These efforts of local governments to promote local economic revival and the development of tourism based on geology may be very suitable for aesthetic appreciation for all people. Moreover, these local governments' efforts may present good opportunities for us to pay more attention to geoscience education and enhance K-12 students' scientific literacy. One of the goal of science education in the revised curriculum of 2015 is to foster scientific literacy for all students to help them understand scientific concepts, build their scientific exploration skills, solve individual and social problems, and develop scientifically and creatively (Ministry of Education, 2015). In light of this, in this study we would like to focus on geology learning using feasible topics in geoscience education.

Students can have ongoing interactions with each other while experiencing scientific exploratory activities such as observation, experimentation, discussion that are used to solve scientific problems. They can generate scientific knowledge when communicating with others. The learning process can be understood as social constructivism that occurs during the interaction of language, culture, and social context. Moreover, students' language can be viewed not only as communication but also as a learning process of knowledge generation within a social and cultural background. Students' interactions have demonstrated essential factors of science learning. Gestures are spontaneous hand movements that accompany speech during interactions (McNeill, 1992). Previous research has found that producing gestures helps children learn. For

example, encouraging students to gesture either before or during a lesson leads to improved performance in psychological science and cognitive development (Goldin-Meadow et al., 2001; Goldin-Meadow et al., 2009).

In geoscience education in particular, the use of gestures is an integral part of communication for novices and experts to describe spatio-temporal properties (Kastens et al., 2008). In addition, gestures not only to enrich the meaning of writing or speech but also to help students interact with each other and facilitate memory (Chartrand & Bargh, 1999). To better understand students' interactions more deeply, we need to explore how students' gestures may affect learners' thinking processes and articulate the difference between misunderstanding and learning knowledge correctly in students' speech. It is necessary to explore how students' gestures in a geology learning environment complement their communication.

We addressed the following research questions to explore students' gestures in the context of a geological field trip:

1. What types of gesture occur during a geological field trip?
2. What are characteristics of students' gestures during a geological field trip?

2 Theoretical Background

2.1 *Geological Field Trip in Geology*

A review of the literature showed that field trips are an important resource for student learning in geology (Kern & Carpenter, 1986; Mogk & Goodwin, 2012). Among the various benefits are that participating in field trips is an essential part of learning and teaching geology (Hodson 1988; Orion & Hofstein 1994). Field trip experience helps students observe, memorize, and recall facts (Orion & Hofstein, 1991). This has been supported by studies that have shown that students who participate in field activity show greater outcomes of practices (Esteves et al., 2015). Elkins and Elkins (2007) emphasized that students need to know the importance of geological field trips in order to gain knowledge in fieldwork. Field classes may play a motivating role in learning in geoscience and are a great opportunity for students to develop cooperation, teamwork, and creativity. They are an indispensable part of students' socialization into the community of geoscience education. Field trip programs are trips in which the instructor takes a class on multi-stop trip, from a few hours to a few days, to see aspects of local geology pertinent to the coursework. This supplementary work helps students not only have embodied experiences but also develop

spatial skills for learning geology (Hutchins & Renner, 2012; Mogk & Goodwin, 2012). Some geologists feel that field trips are an essential part of teaching and learning in geology (De-Paor & Whitmeyer, 2009).

Field classes are aimed at students having interactions with objects, natural phenomena, and other things. Not only students exist as isolated activities, but also they should consider interactions with learners, environments, and instructor through outdoor activities (Orion & Hofstein, 1994). Field trips should be designed for students to engage in activity, participate in learning, and develop their geological knowledge. It is impossible to exaggerate the importance of field classes. Fieldwork activities not only train geologists to conduct research in the field of geology, but also to work on geological concepts, skills, and attitudes to help the student understand and interpret the natural environment. They also help students realize how scientific knowledge contributes to the development of humanity and the social environment (Ambers, 2005; Elkins & Elkins, 2007; Gonzales & Semken, 2009). For these reasons it is important for earth science educators to investigate how to most effectively support student learning while participating in field trips. An under-examined area that may have significant importance in geological field trips is the role of gestures in teaching and learning.

2.2 *Gestures*

Research about gestures began a few decades ago. Gestures are tools for non-verbal communication and mutually complement language rather than being separate from it. Many previous studies on gestures have focused on cognitive development and cognitive psychology. Recently, research has been done on how gestures can lead learners to new ideas or scientific concepts in science content knowledge and cognitive science (Novack & Goldin-Meadow, 2017). In addition, gestures can be useful for emphasizing aspects of speech or to fill a gap when the user lacks the vocabulary to concretely describe something with speech (Roth, 2000). Cognitive science has shown that students use gestures to express abstract ideas and give concrete meaning when solving problems (Alibali & Goldin-Meadow, 1993). While there is no doubt that gestures are an essential part of non-verbal communication, until recently, there has been limited research on the role of gestures in the teaching and learning of geology.

Geology contains multi-dimensional information including time-period (past, past to present, and present), multiple spaces or both in related to between them, and multi-dimension information such as 3D and 4D. To make sense of multi-dimensional information, teachers and students may rely on gestures to help convey information about geological features, concepts, and processes and to externally represent different aspects of geological thinking

(Liben et al., 2010). Research on gesture use in geology has shown that both novices and experts produce gestures to aid communication and thinking and to represent spatial and temporal concepts (Alles & Riggs, 2011; Atit et al., 2013, 2014, 2015; Herrera & Riggs, 2013). Some research has also examined the meanings of both students' and experts' gestures in the context of geological learning (Kastens et al., 2008). More recently, studies have begun to explore gesture use in geological learning environments that focuses on how teachers and students communicate understandings of specific geological features and processes, such as sedimentary rock formation (Herrera & Riggs, 2013) and sedimentary structures (Van Boening & Riggs, 2020). These studies have shown that students and teachers use gestures to convey concepts and processes of varying degrees of sophistication. However, these studies have all been conducted at the undergraduate levels and between instructors and students with relatively advanced knowledge about geology.

To date, there are no studies exploring gesture use by secondary school students and the study of gestures in geoscience education in Korea has been rare. In addition, while studies have examined gestures used when verbally describing and sharing scientific ideas and opinions, no studies have examined gesture use while engaging in problem solving activities. This study seeks to fill these gaps by exploring the role of gesture use by middle school students while participating in geological field trips tasked with problem solving activities. Specifically, this study uses a hermeneutical theoretical framework to understand the meaning of middle school students' gestures in the context of an outdoor geological field trip focused on learning about the formation of the Hantan-River¹. In the sections that follow, we describe hermeneutics and the research design.

2.3 *Hermeneutics*

Hermeneutics is defined as a theory used to analyze human understanding (Glesne, 2016). Hermeneutics involves the use of contextual knowledge, on the part of the researchers, to interpret meaning from verbal (speech) and nonverbal (gestures, text, and silence) forms of communication. From a hermeneutics perspective, interpretation is an important part of understanding human interactions and how humans develop knowledge (Glesne, 2016) and can be used to understand student to student relationships or the relationships between a student and the natural environment (Shane, 2007). Other researchers have found the hermeneutics perspective to be helpful for meaning-making

1 Volcanic eruptions were described as one of the main factors to explain the process of formation of the river.

of students' interactions in the context of outdoor learning situations (Patton, 2002) and during geological field trips (Van Boening & Riggs, 2020). For this study, researchers relied on hermeneutics to interpret the meaning of students' speech and gestures during fieldwork activities while learning about river formation.

3 Research Method

3.1 *Research Procedure and Participants*

3.1.1 Research Procedure

The design for this study was informed by previous research about how to effectively design students' field-trip activities and research about the use of gestures and while participating in geological field trips. Orion's (1993) concept of thinking about field trip settings as a novelty space, which includes psychological factors, cognitive factors and geographical factors that define the field trip learning environment helped to inform the design of our activities. For example, we made sure to provide pre-field visit activities to reduce stress and distractions caused by the novelty of the experience because reducing the novelty space can facilitate more meaningful learning for students during field trips because students can focus on the task rather than be distracted by the novelty of the situation. Additionally, we adapted our research design from previous studies using video to capture and analyze gestures using contextual clues (see for examples, Atit et al., 2014, 2015; Van Boening & Riggs, 2020). In these studies, classification schemes to categorize and describe hand gestures are applied to gestures used during teaching and learning of geology. In this research, we also adapted and modified a classification scheme previously developed by McNeill (1992). This classification scheme was used to help interpret students' gesture use during a geological field trip program implemented with ten middle school students participating in a four-week program taught at a gifted science center in Seoul. The sections below provide more details about the participants and the research methods.

3.1.2 Participants

Ten participants volunteered for this study, of whom six were in eighth grade and four were in ninth grade. Students who participated in this program were selected based on high scores on a series of personality and aptitude tests administered by the gifted science center and based on evidence of high academic achievement in grade seven. All students participated in this research voluntarily with the consent of their parents.

3.2 Data Collection Data Analysis

3.2.1 Data Collection

Data was collected over a period of four weeks while the ten students participated in both geological field trips and classroom-based activities. In this paper, we will focus attention on data collection during the field trip experiences. During the field trips, participants were given time to experience and sketch what they observed, such as rocks, minerals, geological structures, and visible characteristics. They also engaged in taking notes to convey geological information in order to communicate each with each other. For example, participants not only separated types of rocks (igneous, sedimentary, and metamorphic) that they had seen but also took notes to elucidate features of structure, such as pillow lava and joint. They also made models to explain how the Hantan-River was formed.

During each of the field activities, researchers collected three categories of data: a) notes and models students made to describe what they observed and that explained what was happening using drawings and text (examples shown in Figures 1 and 2); b) video and audio recordings of all field trip related activities to capture and video record student gestures; and c) audio recorded semi-structured interviews with students to member-check our interpretations with their intent.

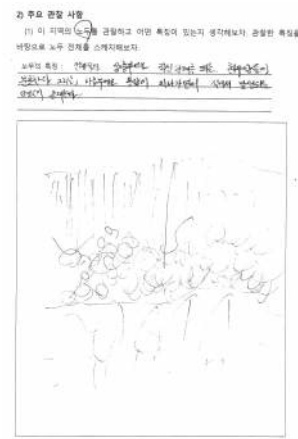


FIGURE 1
Sketch of pillow lava



FIGURE 2
Individual model of how the
Hantan-River was formed

After the 4-week program concluded, the researchers asked students to participate in an open-ended interview. Common questions involved, a) explaining how the Hantan-River was formed with a request to specifically describe the process of its formation and b) member-checking the intent on the gestures used by students when communicating with one another during the field trips. The goal of the interviews was to member-check our interpretation of students' gestures and accompanying speech used during the field-trip problem solving activities.

4 Data Analysis

We used a hermeneutics perspective to delineate meanings of the students' gestures or the goals of their gestures in this study. The hermeneutics perspective is consistent with the use of methodology that combines observation, interpretation, and classification of gestures during data collection and analysis. We focused on understanding students' ideas and the geological meaning conveyed during fieldwork when participants observed, sketched, and interpreted natural geological phenomena (Kafle, 2011; Van Manuen, 2016). To determine what was being communicated by the gestures, we considered the participants' coinciding discourse about geological surroundings and concepts (Koch, 1999). We drew from McNeill's (1992) scheme categorizing gestures to support our interpretation. This scheme has been widely used by researchers exploring the meaning of gestures in communications and has been applied in several studies of gestures in geological sciences (see Van & Riggs, 2020).

Specifically, we used his categorization scheme to identify types of gestures (e.g., iconic, metaphors, deictics, beat, and butterfly) and functions of gestures. McNeill's (1992) scheme relies on other contexts to understand the meanings of the gestures. Previous researchers have noted there is some limitation in using this scheme, which is that this classification method was not intended to identify gestures used in science education (Van Boening & Riggs, 2020) and some gestures may not conform to all classification schemes (Goodwin, 2003). For example, McNeill's (1992) scheme is highly reliant on speech to meaning of gestures. Moreover, geology is domain specific and includes a lot of information from both in and out of school and requires analysis of gestures from interactions between students and nature, students and peers, and students and the teacher. For this reason, gestures used in one context may have specific and different meaning in a geological context. To support our interpretation of geological gestures and our application of McNeill's gesture classification scheme, we employed schemes adapted by studies about gestures in geological

contexts (Alles & Riggs, 2011; Kastens et al., 2008; Van Boening & Riggs, 2020) and we revised McNeill's (1992) original scheme to propose a new more comprehensive classifications of gestures useful to describing river formation by novice students on a geological field trip.

We applied the same analytic process described by McNeill (1992, 2005) to identify and separate each gesture into discrete analytical units, meaning we developed a scheme for establishing when a gesture begins, when the full structure of the gesture peaks, and when it ends. These three phases are referred to as the preparation, mid-stroke, and retraction phases, respectively. After identifying and parsing gestures into discrete analytical units, we began to focus on interpreting the meaning of the gestures. To do this, we first focused on sorting the gestures into groups based on the types of gestures that occurred. Next, we captured students' gestures and speech together and transcribed the speech and described in detail the movement that was elicited in conjunction with speaking or writing/drawing. Once we had detailed transcriptions and descriptions of speech and movement associated with each discrete gesture, we focused our attention interpreting what meaning the gestures and speech were intended to convey given the context of the interaction. The validity of researchers' interpretations of gesture meaning was strengthened by both member-checking with student participants and by ensuring the use of triangulated data sources (student and observer notes, audio-visual recordings, and interviews) to provide rich context for interpretation.




5 Results

There has been little recent literature on gestures in Korea that has focused on middle school students' gestures, where they are used to help with understanding in students' communication because of insufficient resources in geology knowledge. The purpose of this research was to identify and classify students' gestures and to understand the meaning of students' gestures in relation problem-solving activities about the geological process of river formation. In this section, we share two findings: 1) definitions and examples of the three most commonly observed gestures employed by students during field investigations and 2) a description of gestures commonly employed by students when engaged in explaining, asking, insisting, and giving evidence.

5.1 *Types of Students' Gesture Occur in Geological Field Trip*

Our analysis revealed there were three commonly occurring gesture types (as categorized by McNeill, 1992) that occurred during the field trips. These

TABLE 1 Definitions of the three gesture types: deictic, imageable, and depictive

Gesture type	Description	Speech	Example (Mid-stroke)	Proportion of gestures observed
Deictic gesture	Deictic gestures may be used to indicate a feature, object, etc., or indicate a specific direction of something.	A Student 1: "The black part at the bottom is a little different." A Student 2: "Where?"		80.24% (<i>n</i> = 65)
Imageable gesture	Imageable gestures may be used to delineate a visual image of something in the past that cannot be seen	Teacher: "How was the columnar joint formed?" B Student 1: "The magma soooopp (mimic word)"		12.35% (<i>n</i> = 10)
Depictive gesture	Depictive gestures may be used to delineate a visual image of something visible in the present	Teacher: "How does shape of middle layer?" C student 4: "lying down like this a square"		7.41% (<i>n</i> = 6)

gestures can be described as deictic, imageable, and depictive. In this section we describe the frequency of use and offer examples.

5.1.1 Deictic gestures

Deictic gestures are described as gestures use to point out concrete or abstract objects or events (McNeill, 1992). This gesture was identified 65 times and accounts for about 80% of all gestures (see Table 1). In our study, we found that several types of action involved pointing at something or indicating a space or object. For instance, when students explained features of striped rocks, they separated them into three types of rocks (igneous, sedimentary, and metamorphic) using just observation. In this case, meaning-making and sharing of their geological ideas may have influenced pointing. Deictic gestures not only had meaning in representatively indicating objects and specific space, but were also used to communicate information when students were pointing out something in an unfamiliar environment or situation or when students lacked the vocabulary words needed to name an object or process.

5.1.2 Imageable Gestures

Imageable gestures were used when students were making meaning of unobservable and invisible objects in order to represent a visual image. These

images were used when students wanted to convey movement that was not possible to see with the human eye (like movement of UV light) or activity that occurred in the past (like lava flow). In particular, students used imageable gestures rather than verbal language when explaining how the Hantan-River was formed. Students used imageable gestures to demonstrate the formation of pillow lava, which are columnar joints caused by volcanic eruption. They used visual images to emphasize movement of flow lava and processes of eruption movements in the past. Imageable gestures occurred at the second-highest frequency ($n = 12$, $\sim 12\%$) during the field trip and were used especially for things that were not clear or to portray a process that occurred in the past using a visual form.

5.1.3 Depictive Gestures

The most infrequently used ($n = 6$, $\sim 7.4\%$) gestures were classified as depictive gestures. These are movements that occurred when students made visual representations to express what they directly observed in the present. For example, a participant used a depictive gesture to point out the round shape made by pillow lava of a tile and pillar (see Table 1). Another example is when students depicted what they directly observed while sharing their ideas and observations with others. Although depictive gestures were used the least, they were essential in situations in which where students needed to convey their observations to others.

5.2 *Meaning of Students' Gestures During a Geological Field Trip*

The second goal of this research was to interpret the meaning of students' gestures when communicating during geological field trips. However, because students enacted many gestures during the field trips, we further classified the gestures into categories based on the purpose or intent of the gesture. The categories included gestures that served a social purpose for communicating ideas (explaining, asking, insisting, and giving evidence) and gestures related to communication of scientific content (visualization and temporal or spatial). In the sections that follow we describe both in more detail.

5.2.1 Social Role Gestures

Gestures that played a role in organizing social interactions during communications were classified into four groups based on the function of the gesture. These included gestures used to explain, ask, insist, and give evidence. Below we explain and provide examples of each.

Explain. Movements used to explain something, convey information, and share ideas were the most common among students' gestures ($n = 41$; 51%) and accounted for about half of all observed gestures. Students may be limited

TABLE 2 Definitions of four gesture functions and examples of each gesture type for social role category

Gesture function		Gesture description	Speech	Example (Mid-stroke)	Context description
Social-role	<i>Explain</i>	Explain gestures commonly consist of deictic gestures. Some of them utilize deictic, imageable, and depictive. 50.6% (<i>n</i> = 41)	C student 3: “This rock has rough along here. And round shape.”		Explaining the shape or outline of rocks’ structures that are visible to them
	<i>Ask</i>	All ask gestures are deictic. 30.9% (<i>n</i> = 25)	C student 2: “How joint was formed over there?”		Asking the teacher (wearing striped T-shirt) about joint formation
	<i>Insist</i>	Insist gestures commonly consist of deictic gestures. Some of them utilize deictic and imageable. 12.4% (<i>n</i> = 10)	Teacher: “How joints was formed?” C student 3: “Shuwook, Sak, Swee....” (mimicking words)		Insisting how columnar joints were formed
	<i>Give evidence</i>	All give evidence gestures consist of deictic gestures. 6.1% (<i>n</i> = 5)	B student 2: “This is a feldspar, and then it is a quartz.”		Looking for feldspar and quartz to find granite in sedimentary sand next to the river course

in using scientific explanations in their communication processes because they lacked geological background resources. In this case, they may rely on gestures to supplement scientific knowledge. For example, as students were identifying the rock structure of pillow lava, the students commonly indicated an outcrop by using their hands. The explain gesture was used to introduce peers to what was directly observed and to describe a geological feature by pointing out something. In this case, deictic gestures were used to indicate a subject or object to convey information in order to help communication.

However, students also conveyed information using imageable and depictive gestures too.

Ask. This gesture is characterized as a movement used by teacher or student to ask about something they were curious about or had an interest in. This kind of gesture was the second most frequently used gesture ($n = 25$; 31%). For instance, we observed many examples of students gesturing as they used a tool to indicate an object in which they were curious or when wondering how a joint was formed, indicating interest by pointing to the location of the joint. All ask gestures were deictic and students used these gestures to communicate about objects that were unfamiliar to them because they lacked prior knowledge of rocks and geological structures. Experts, however, may be able to use more dynamic movements to pose questions about specific knowledge or concepts.



Insist. This gesture is characterized as a movement made when students insisted on what they thought. In one example, a teacher asked a student how a columnar joint was formed and the student was making an inference about the three locations they had visited when by using gestures to elucidate how columns structures were formed by repeated volcanic eruptions. To insist the point, the student used repeated and exaggerated gestures to add emphasis rather than words. The students' gestures were a form of expression available to him that he could use to convey the feature being referenced. Not all insist gestures consisted of repeated gestures, but when students frequently repeated a deictic gesture, it generally served the purpose of conveying information clearly and emphatically. This kind of gesture was not used frequently ($n = 10$; 12%)

Give Evidence. This gesture is characterized as a movement that helped to support an idea. It was the least frequently gesture ($n = 5$; 6%) and was always classified as deictic. For example, while trying to confirm the river flow, a student was categorizing types of rock in the sand and found both quartz and feldspar. Students had examined rocks near Jwasang-bawi (a rock formation along the Hantan-River) to identify the characteristics of igneous, sedimentary, and metamorphic rocks and were comparing formulaic rock samples to categorize to distinguish which rocks from minerals. When working in small groups to categorize unknown rock samples, students employed give evidence gestures to indicate more information was needed before identifying a sample as being a rock or mineral.

5.2.2 Scientific Content Gestures

Gestures that played a role in communicating scientific content were classified into two groups based on the function of the gesture. These included gestures

TABLE 3 Definitions of gesture functions and examples of each gesture type for scientific content category

Gesture function		Gesture description	Speech	Example (Mid-stroke)	Context description
Scientific-content	<i>Visualization</i>	Visualization gestures commonly utilize imageable, depictive, and deictic gestures. 41.4% ($n = 36$)	B student 2: “Gas release caused a hole”		Expressing the release of gas that made a hole in the basalt.
	<i>Temporal or spatial</i>	Temporal or spatial gestures commonly utilize deictic, imageable, and depictive. 58.6% ($n = 51$)	B student 1: “Sediments, accumulating comes first following this layer. Next, lava flow comes here.”		Indicating following layers to elucidate lava flow in the past.

used for visualization of content and for explaining content related to time or space. Unlike gestures with social roles, the gestures used to convey scientific-content are not necessarily expressed as a single gesture and they often are combined to express both visualization and temporal/spatial concepts simultaneously. Below we explain each and provide examples.

Visualization. These gestures were generally performed to visualize movement. For example, a representative visualization gesture occurred when a student observed basalt and then used gestures to explained how basalt stoma are formed by gas being released under great pressure. In this example, the visualization consisted of combination of deictic, imageable, and depictive gestures. Because students lacked geological background knowledge as a resource for discussing processes, they frequently ($n = 36$; 41%) made use of visualization gestures to explain scientific content to their peers and teacher.

Temporal or spatial. Unlike other content areas, gestures used to convey time or spaces are prominently used because geological processes occur in large scale and over long time periods. Students used this category of gesture more frequently than all other gesture types ($n = 51$; 59%). Examples included when students observed layers of rocks and they made sketches of features of each

layer and a teacher asked students to consider the order in which the layers were deposited. Students pointed at the layers between the bank of the river and along the joint of the river and used gestures to reflect the formation of the Hantan-River bank by demonstrating the gradual depositing of each layer through repeated motions in the same space and over long periods of time.

6 Conclusion and Discussion

The purpose of this study was to explore middle school students' gestures during a geological field trip. Much previous research has focused on upper-level geology students, such as undergraduate geology majors and geology faculty, who have access to a great deal of geological background knowledge to draw from as a resource. This study, however, aimed at studying the meanings of gestures of middle school students, who lack a background in geology and who may rely more extensively on non-verbal interactions to communicate their understandings while on a geological field trip. A recent study by Van Boening and Riggs (2020) involving undergraduate students with strong backgrounds in geology, categorized five types of gestures used when students engaged in fieldwork activities. This study adds to this work by introducing new categories of gestures used by younger students with less background knowledge from which to support their verbal descriptions of geologic processes associated with the formation of the Hantan-River. This study showed that middle school students made use of various gestures to describe river formation processes from repeated volcanic eruptions.

Similar to other studies that have described and interpreted gesture use in geology using McNeill's classification, we found that not all gestures fit this pre-established classification scheme and instead require more categories to capture the full range of gestures used to convey geological understandings of middle school students doing field work. The identification of new and more gestures can better support geo-science educators to provide students with more resources for their learning. Categorizing gestures based on type and function offers educators a better appreciation for the role that context plays in gesture use. In our research, we found that gestures played a social organizing function and a scientific content function and students made use of gestures to communicate a wide variety of meanings.

The new categories introduced in this research offer educators and students more tools for enriching communication and understanding in geology, and especially while engaging in fieldwork. More exploration is needed to consider how educators might make explicit use of different kinds of gestures in their

teaching and to determine the effectiveness of gesture use for students' learning. This is an important area for future research.

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Ethical Considerations

Approval to conduct this study was granted by the Seoul National University Ethics Review Board. The data collected from this project has obtained the necessary clearance from the guardians and the students involved in the study. The names of the participants used in this study are all pseudonyms.

About the Authors

Yoon-Sung Choi received a doctor's degree from the Department of Science Education at Seoul National University in Seoul, Republic of Korea. He is interested in improving geoscience education programs for learning about a geological field trip. In particular, my research focuses on students' nonverbal interaction to develop understand their communication in geoscience education programs. My research aims to analyze students' gestures in geoscience education programs to find and implement improvements.

Seung-Urn Choe is emeritus professor in the Department of Earth Science Education at Seoul National University in Seoul, Republic of Korea. He holds a bachelor's and master's degree from the Department of Astronomy, Seoul National University. He also holds a Ph.D. in Astrophysics from the University of Minnesota in the United States. With a focus on scientific modeling, he developed and applied a variety of educational programs that enable students to socially construct scientific models. His research covers a variety of topics,

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Chan-Jong Kim is Professor in the Department of Earth Science Education at Seoul National University in Seoul, Republic of Korea. He received his bachelor's degree in Earth Science Education and master's degree in Geological Sciences from Seoul National University in the Republic of Korea. He also holds a doctoral degree in Science Education from the University of Texas at Austin in the United States. His research focuses on scientific modeling as an approach to scientific exploration and learning in a variety of subjects, contents, and contexts and on development and application of various methods for the analysis of collective talk with learning of science. He is particularly interested in education for diverse learners in Korean K-12 on global environmental risks such as climate change.

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