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THE TYPES OF PEER SCAFFOLDING IN SCIENTIFIC EXPERIMENTAL ACTIVITIES

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Abstract. *This study studied the types of peer scaffolding presented in scientific experimental activities. The study included 14 university students. For the experimental activity of 'determining temperature changes using the meridian altitude of the sun,' information regarding experimental behaviors, thinking aloud, discourse, and retrospective interview data were collected and analyzed. A model was derived and utilized for experimental activities to analyze peer scaffolding, wherein students internally structured their experiences with the experimental activities. The results indicated that students utilized seven means of peer scaffolding: 'demonstrating', 'assisting', 'monitoring', 'posing', 'questioning', 'explaining', and 'suggesting'. Three types of peer scaffolding emerged: task completion-, model elaboration-, and learning support-oriented scaffolding. Each type differed in purpose, main mean, and major explanation details. Additionally, this study has observed the level of the model for the experimental activities and the time that had been provided to understand the experimental procedure influenced the three peer scaffolding types. These outcomes indicate that providing ample time to students independently structure the experimental procedure and supporting other students during experimental activities are essential. Moreover, providing assistance to students in focusing on observable phenomena by reducing the cognitive load required to process the experimental procedure is crucial.*

Keywords: *peer scaffolding, scientific experimental activities, students' interaction, qualitative case study*

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Introduction

'Scientific experimental activities' are considered essential in science classes. In the classes, students could have the opportunities to reproduce 'real natural phenomena' through scientific experimental activities. Through the activities, students would have the chance to observe the phenomena and connect the natural world with internal representations through observation of phenomena. Scientific experimental activity is a unique teaching and learning method used in science subjects (Hofstein & Lunetta, 2004). This teaching and learning strategy is broadly used worldwide for teaching science in primary, lower-secondary, and upper-secondary school (Kipnis & Hofstein, 2007). Through scientific experimental activities, students can develop abilities considered important in science education (Hofstein & Lunetta, 2004). In particular, because students can achieve certain learning goals in these scientific experimental activities, contexts where learners are exposed to the chance for the actual experience, experience in scientific experimental activities is paramount for learners (Girault et al., 2012; Tiberghien et al., 2001).

The learning environment in an experimental activity is composed of factors such as the student, teacher, experiment manual, and materials. Among these factors, the interaction between students through conversations and behaviors is frequent and critical for learning (Roth, 2006). Scholars have argued that collaborative experimental activities in small groups are enough to afford more chances of interactive communication (Andersson & Enghag, 2017), more effective than those performed in individual groups in various aspects (Bilgin, 2006; Hofstein et al., 2005; Howe et al., 2007). Furthermore, these activities offer more opportunities to participate in important cognitive activities such as planning for experimental activities and monitoring (Lin et al., 2001; Shi, 2013). Nevertheless, studies reviewing the interaction among students during experimental activities have been relatively few (Raviv et al., 2019; Wei et al., 2019).

Students actively use their own previous experiences in experimental activities (Högström et al., 2010). In the class environment, spontaneous interactions manifest based on the students' diverse knowledge and prior experiences. Supplemental assistance in the form of assisting students in participating in learning tasks during interaction with peers is referred to as peer scaffolding (Kim & Hannafin, 2011). Assistance from a peer with a similar level of knowledge is as important as that from a teacher. Through peer scaffolding, phenomenon observation, inferencing on the observed phenomenon, clarifying explanation of a phenomenon, and stimulating thoughts that operate to connect the just-heard-explanation with the concepts that they already know could be facilitated. So, students need to listen

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to queries from others (Driver, 2012). Peer scaffolding promotes knowledge restructuring by enabling students to recognize differences in knowledge, beliefs, and experiences between themselves and peers, as well as to experience cognitive conflicts (Palincsar et al., 1987). Moreover, students encounter diverse experiences by perceiving differences from their peers and endeavoring to bridge these gaps (Choi et al., 2005).

However, research on peer scaffolding regarding scientific activities is relatively inadequate. Kim and Hannafin (2011) argued that peer scaffolding effectively facilitates scientific problem-solving by promoting a reflective discourse between students. In addition, Shin et al. (2020) identified nine types of peer scaffolding in inquiry-based learning. They also found that the interaction patterns depended on the level of knowledge of each group. However, other studies on peer scaffolding have mainly focused on peer scaffolding appearing in online contexts. Research on peer scaffolding during actual face-to-face interactions has not been spotlighted. Furthermore, there seem to have been no studies focusing on peer scaffolding in experimental activities yet. Therefore, the characteristics and usefulness of peer scaffolding that students demonstrate during experimental activities still remain unknown.

As such, this study has analyzed peer scaffolding shown in scientific experimental activities. In this manner, this study provides implications regarding measures that should be implemented to facilitate scientific experimental activities effectively. Specifically, this study presents an empirical answer to the following question: What kinds of peer scaffolding appear in scientific experimental activities in the Korean science classroom?

Theoretical Background

Student Behaviors in Scientific Experimental Activities

Scientific experimental activities in primary, lower-secondary, and upper-secondary schools in Korea and other countries worldwide primarily comprise a verification experiment and a discovery experiment (Domin, 2007; Tiberghien et al., 2001; Yang et al., 2007). These types of scientific activities require an experimental manual that describes the experimental procedure. Various kinds of empirical evidence have indicated that students focus more on following the experimental procedure rather than learning the intended contents (Abrahams & Miller, 2008; Högström et al., 2010; Osborne, 1993; Tamir & Lunetta, 1981). Students spend most of the time on the experimental procedure's manipulative aspects using a low skill level. Students are somewhat seemingly interested in completing laboratory tasks instead of the concepts and functions that the teacher aims to teach the students through scientific experimental activities (Berry et al., 1999).

The cause of such scientific experimental behavior of students is due to the difficulty of processing the experimental procedure. A new experiment is filled with a plethora of information, including difficult terms, materials, and scientific concepts (Gunstone & Champagne, 1990). Students should understand and manage the procedure, which is constructed with new information (Lehman, 1990). Moreover, because of the newly exposed and stimulating phenomena that students experience in experimental activities, they neglect the aspects they should observe (Johnstone & Al-Shuaili, 2001). Students are also required to invest various cognitive resources to connect the experimental activity results to abstract concepts (Hodson, 1993). Johnstone (1997) explained that the students' information processing during a scientific experimental activity is perceived and filtered by the boundary the students know and afford to understand. Accordingly, the students would not recognize the information outside the perceived boundary. Therefore, it cannot convey its entirety. In addition to this, Johnstone pointed out that due to the excessive information, students may experience a cognitive load. Therefore, students cannot express the current activity and the reason for conducting it even after its completion (Gunstone, 1991; Hodson, 1993; Hofstein & Lunetta, 2004).

Many scholars on science education possess a skeptical point of view regarding the effectiveness of scientific experimental activities (Abrahams & Miller, 2008; Hodson, 1993; Hofstein & Lunetta, 2004; Tiberghien et al., 2001). Not only trying to students experience various abilities of science subject intended to teach, but also trying to teach them by providing direct experience on scientists' activities was challenging. This is because students do not possess the abundant experience or theoretical elaboration of scientists (Kirschner, 1992).

Student–Student Interaction in Scientific Experimental Activities

Scientific experimental activities offer opportunities for various types of student-student interactions (Hofstein & Lunetta, 2004). In the activities, cooperative operation activities, communication of discussion and

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demonstration, and various forms of problem-solving require collaborative work. In this process, students experience such as the elaboration of scientific explanation, exchange and expansion of ideas, negotiation, observation and imitation of diverse functions, use of scientific language, and other variegated experiences (Hofstein et al., 2005; Howe et al., 2007; Olubu 2015). Such experiences of interaction have advantages in various aspects. For example, they positively influence not only both cognitive and affective aspects but also economic aspects (Raviv et al., 2019) of improving achievement (Keys, 1996; Lazarowitz & Karsenty, 1990), improving inquiry ability (Hofstein et al., 2005; Lazarowitz & Karsenty, 1990), understanding the collaborative character of generating scientific knowledge (Lunetta et al., 2007), and forming a sound learning atmosphere (DeCarlo & Rubba, 1994). Meanwhile, previous studies have reported that the activities may be less effective unless teachers proactively intervene in the students' interaction (Alton-Lee et al., 1993). Others also argued that group activities are more time-consuming and require more teacher effort than individual activities (Clyde, 1998; Raviv et al., 2019).

Precedent Research on Peer Scaffolding in Scientific Learning Situations

Research on peer scaffolding concerning scientific teaching and learning has mainly focused on online learning environments. However, in studies on peer scaffolding during face-to-face classes, Kim and Hannafin (2011) and Shin et al. (2020) analyzed the araising patterns of peer scaffolding through web-based exploratory learning.

Kim and Hannafin (2011) analyzed the scientific problem-solving process presented by students in technology-enhanced science classrooms by observing two classes in the 6th grade. They researched the effects of peer, teacher, and technology-enhanced scaffolds on the inquiry activity of students. As a result of the study, the types of peers, teachers, and technology-enhanced scaffolds were derived. It was revealed that a distinct inquiry pattern occurs in students' problem-solving processes. They also illustrated that disparate types of scaffolds are integrated to facilitate the inquiry activities of students.

In Shin et al. (2020)' study, they researched inquiry-based, web-based learning materials of six classes in the 9th grade. They also observed the peer scaffolding that appeared in the classes. Based on the findings, they distinguished the types and patterns of peer scaffolding. In addition, according to each group's knowledge level that was classified as high, blended, and low levels based on already measured prior knowledge of the students; they could confirm the newly revealed patterns of the scaffolding of the students. Peer scaffolding requires knowledge about each area and metacognitive skills, and the quality of peer scaffolding influences the students' prior knowledge level.

Still, peer scaffolding revealed in face-to-face scientific classroom environments remains only partially understood. These findings indicate that peer scaffolding research is useful in terms of showing various aspects of students' learning of science. The results also reveal the need for effective peer scaffolding to increase the effectiveness of learning science.

In this study, peer scaffolding in scientific experimental activities is studied. Scientific experimental activities play a central role in learning school science, and this has been proved through various research concerning the activity. However, peer scaffolding occurring within the activities has not been deeply studied and has only partially been understood. This study spotlights the peer scaffolding occurrence in scientific experimental activities. By doing so, this study raises the importance of understanding peer scaffolding appearing in scientific activities that use real objects included in the scientific experiment activities.

Research Methodology

Background

This study used the method of qualitative case studies to analyze how peer scaffolding appears in each case where students' cooperative experimental activities are conducted. This study collected students' experimental activity experiences in various ways, such as observing experimental behavior, thinking aloud, and having a conversation during experimental activities. In addition, retrospective interviews, experimental behavior observation records, and field notes were also created and collected. For the in-depth analysis of the collected data, a model of the experimental activities was derived, and the means of peer scaffolding used by the students were identified. Finally, each case's types of peer scaffolding were classified and analyzed based on the means of peer scaffolding revealed by students' discourse, behavior, and the contents of peer scaffolding.

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Participants

The research participants of this study were fourteen students (five female students and nine male students) enrolled in a four-year national university in South Korea. The university is in the middle of South Korea and is one of the most prominent teacher education universities. The recruitment targeted university students for seamless communication and a smooth simultaneous verbalization of cognition during the experimental activity. In addition, it targeted students undertaking other majors apart from the natural sciences to eliminate any professionality on the task. Because building rapport is vital for the smooth interaction in the task performance of a team comprising two members. In this study, two students already acquainted with each other were recruited as one team. The reason for this group's composition was to reduce the time to build rapport between them. Since they already know each other, they could easily jump into the activity with comfortable interaction. A total of seven cases (six same-gender cases and one mix-gender case) were created. Participants in this study were 18 to 20 years old, and they all were in their first or second grades when the data was collected. The all-research participants were fully informed of the anonymity of their participation. The safety of their participating task was also notified in advance.

Context

The experimental activity needs to reflect small-group activity environments in schools sufficiently. To this end, the experiment of this study was designed by following the consultation of two experts in science education. Two aspects were also discussed with the researcher of this study and the two experts. First, peer scaffolding is possible under the context of natural social interaction. If the role of a tutor is assigned to a participant, then the participant may try to meet the expectations for the assigned role (Roscoe & Chi, 2007), which would render the experimental activity become unnatural. Hence, this study created a situation where two students performed the experimental activity without being assigned special roles and freely cooperating.

Second, one of the two individuals should possess prior experience of the experimental activity for peer scaffolding, as it presumes that one has more knowledge and experience in the small group (Wood et al., 1976). Therefore, it was important to design the format of the group to be one has to experience the experimental activity while the other one has no experience at all. In the first instance, researchers selected an experimental activity that the two individuals in a team had never experienced before. Then, among them, only one was offered a chance to perform the pre-task related to the selected experimental activity. This created the format that one person possesses more knowledge than the other.

Task

To answer the research question of this study, the researcher of this study decided on the following criteria in the task selection: (1) an experiment that fully reflects the science curriculum in Korea; (2) an experiment in which the students did not experience in their school years; (3) an experiment using various and unfamiliar materials and tools; and (4) an experiment at the elementary and middle school levels that is simple enough so that can be solved by students who do not study natural science. Based on the consideration of the four criteria, this study selected the experimental activity entitled 'determining temperature changes according to the meridian altitude of the sun,' which was derived from a sixth-grade science textbook published by Company I. This activity uses a model experiment to investigate temperature differences according to the angle of the sun and the surface of the earth. First, students produced two electric circuits, where a solar panel and a buzzer were connected with an electric wire, then installed each lamp by differing the angle of the bulb and the solar panel. Subsequently, the lamp was shone toward the solar panel to qualitatively observe and compare the volume of sound created by the buzzer. This experiment prompts students to reflect on the seasonal temperature changes that happen as the solar-radiation energy that reaches the surface of the earth varies according to solar altitude.

The experiment manual was created by reflecting the experimental procedure included in the textbook. To aid the understanding of the students and to help them easily visualize the difference in the angles of the lamp and the solar panel, that is, a variable that requires caution, a visual material was additionally inserted at the bottom of the experiment manual (Appendix 1). Through a preliminary experiment conducted by one university student, researchers confirmed that the experiment manual and the experiment materials were free of errors.

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Data Collection

The experiment recruited two participants as one team, where one undertook the experimental activity in advance. In total, the number of participants was 14 students, and they were paired into seven groups. Then, each group started their given experimental activity together.

Figure 1
Data Collection Procedure

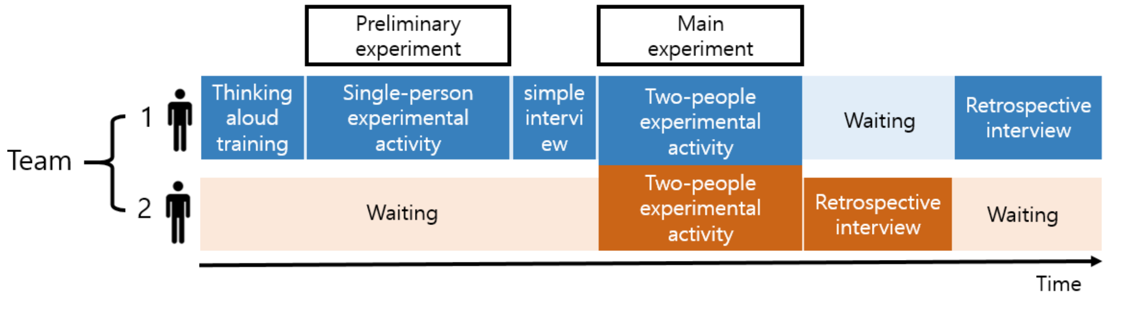

Figure 1 presents the data collection procedure. First, one of the two participants moved to a waiting room separated from the laboratory, then stayed there. To analyze the experience of the participant who performed the experimental activity alone, the process of verbalizing the cognition of the participants was required. Toward this end, 10 to 15 min of 'Thinking Aloud Training' was conducted using a block assembly task. Afterward, the participant independently conducted a preliminary experimental activity and thought aloud simultaneously. After the experiment, an interview was conducted on aspects students found challenging and their impressions of the activity. The instructor of the class paid attention to prevent the interview from being served as a clue about the experimental activity.

In the experiment, the two team members were required to engage in active communication as they performed the experimental activity. All experiments lasted for approximately 20 to 30 minutes, and the experimental activity was recorded using a video camera. The researcher created field notes not only about the behavior but also the discourse of the participants during the experiements. Subsequently, a one-on-one retrospective interview was conducted with each participant. The interview was designed as semi-structured, and the recorded video was used as the cues for retrospective thinking. Based on the field notes, the participants were asked to provide a detailed explanation of each situation and respond to the given questions about their thought at a certain moment during the research process with a detailed description. Several follow-up questions were also provided. The interview lasted approximately 20 min per participant, and all interviews were recorded using a video camera. All data collected in the two-session experiments and the interviews (thinking aloud, a conversation between the participants, and retrospective interviews) were transcribed.

Data Analysis

The patterns of peer scaffolding during the experimental activity appear diversely according to the pairs and the performance of the activity. By using a qualitative case study methodology, this study identified how and why peer scaffolding appears in selected cases. This study also categorized the outcomes according to each type of peer scaffolding. The collected data was analyzed, and the characteristic of the model students composed through their participation in the experimental activity was identified. As the model about the experimental activities becomes the cognitive basis for students to be able to offer peer scaffolding for their colleagues, then, based on the model, the means of peer scaffolding that the students were using were also distinguished. After that, the type of means of peer scaffolding the students employed with his/her pair was analyzed according to each case. At the last stage of the data analysis, the kinds of peer scaffolding the students used were diagnosed. Also, by deducing the model for the experimental activity that becomes the basis of the scaffolding means, the characteristics of the peer scaffolding types were described for each case (see Figure 2).

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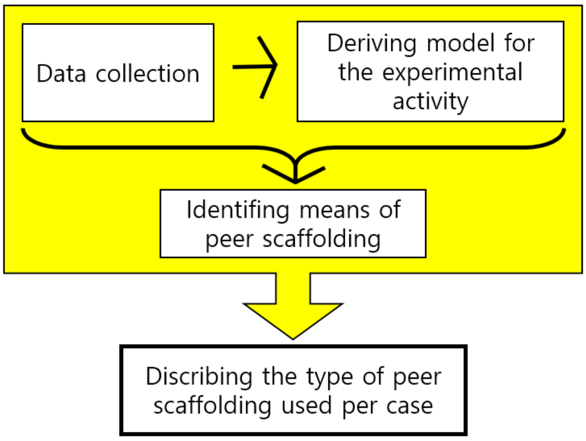
Figure 2
Data Analysis Framework



In peer scaffolding, a student with experience implicitly provides information to the student without prior experience (Shin et al., 2020). Therefore, revealing the type of knowledge foundational to peer scaffolding is essential for the in-depth analysis of peer scaffolding in experimental activity. This study presumed that the participants structure a certain type of model stored in their long-term memory through their experience in the experimental activity. It then explored the type of information that comprises such a model of the experimental activity. To understand the information factors in the model, this study focused on the differences in experimental behavior and language before and after the experimental activity. The reason for doing so was that these differences were caused by the variations in the derived models. The data analysis was conducted by the repeated process of writing down notes while reviewing the transcript, video, and observation records to capture the segments indicating differences in experimental behavior and language before and after the experimental activity. Through this process, the information required of the participant and whether the participant possesses this information could be determined. Subsequently, the types of identified information were named and categorized. Throughout the study, the researchers repeatedly performed the process of writing the line-by-line coding, writing down notes, and checking the collected data to theoretically saturate the information that composed the model. Appendix 2 represents the results.

The model for the experimental activity was comprised of 4 categories and 15 categories of information. It was also task-specific. Rather than independently, the information categories were seemingly used in a complex manner during an interaction with a peer. Meanwhile, the model structured by the participants did not comprise accurate information. During the experimental activity, the model can be structured based on the experience of the participants that differs from the initially intended by the experiment manual. Moreover, the model can be organized according to one's experience with failure. Finally, the model can be modified or elaborated through the experience of additional experimental activity.

Among the 15 categories of information, the *meaning of the procedure* and *how to perform the procedure* were perceived as easily obtained because they were explicitly revealed in the experiment manual. However, the rest of the information could be acquired only through the experience of the actual experimental activity participation, and it could be accumulated by the interaction with the experiment manual and materials. Particularly, meta information on procedure performance was difficult to attain without metacognitive processing during the experimental activity. The perspective of the model for such experimental activity enabled the study to explain the aspects through which students structure knowledge through their experience in the experimental activity and apply it to peer scaffolding.

The next step of data analysis was to identify the means of peer scaffolding. Toward this end, the study conducted the top-down and bottom-up processes of data analysis. The initial coding system was developed based on the types of peer scaffolding suggested by Kim and Hannafin (2011) and Shin et al. (2020), who examined peer scaffolding during scientific activities. The data collected in a multilateral manner were repeatedly examined to

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modify the initial coding system, and the means of peer scaffolding were identified and confirmed through a review conducted by experts outside of the research.

The last step of data analysis was distinguishing the types of peer scaffolding indicated in each case of the seven teams. The types of peer scaffolding per case were identified based on the type of information conveyed and the means and purposes of the respective cases. Furthermore, the researcher described the relationship between each case with the experience in the previous experimental activity. Moreover, the results were used to establish labels for the types of peer scaffolding of each case.

This study used several strategies to ensure the validity and reliability of the qualitative analysis. First, data analysis related to experimental behavior, thinking aloud, conversation during the experimental activity, retrospective interview, and field notes were diversified, and comparative analysis was continually conducted. In addition, the presumption and potential bias of the researcher were self-identified and self-recognized. The researcher of this study had experience instructing students on scientific experimental activities for more than ten years as a science teacher and has frequently participated in science education studies as a qualitative researcher. In addition, throughout the process of analysis, the method was shared and discussed with an expert in science education with more than 20 years of experience in qualitative research. The final analysis then categorized data were reviewed through a discussion with one of the participants of this study.

Research Results

Identification of Peer Scaffolding Means during the Scientific Experimental Activity

Peer scaffolding can be diversely provided according to the means and objectives through which it is provided. The results revealed seven means of peer scaffolding: 'demonstrating', 'assisting', 'monitoring', 'posing', 'questioning', 'explaining', and 'suggesting'.

Demonstrating

The most frequently observed mean of peer scaffolding was 'demonstrating,' in which the procedural implementation was directly shown to the peer through actions. 'Demonstrating' emerged along with 'explaining.' As the student personally illustrated the experimental procedure, s/he explained to the peer the current process and the reason for following the procedure. Providing 'demonstrating' would enable the other peer to observe, imitate, then understand the procedure. The below example was the part of the discourse of Team E on the implementation of procedures 1 and 3. Students no.1 per every term has experience in conducting the experiment, and every no. 2 students per every team have no experience in the experimental activity.

E1: I will connect this here … (connects the solar panel and the buzzer with electric wire)
E2: Ah … (sees and imitates E1's operational situation)
(omitted)
E1: A sound will be made when I turn on the lamp, like this. One, two, three! (personally, turns on the lamp)
E2: Oh, I can hear the sound.
E1: Now, I will check which sound is louder according to the angle difference.
<Procedures 1 and 3; Team E main experiment>

For instance, in the case of Team E, when making an electric circuit that connects the solar panel and the buzzer with the electric wire, the one student (E1) allowed the other student(E2) to understand the procedural implementation, then led E2 to conduct the rest through imitation by personally demonstrating the process. In the meantime, many cases occurred in which the no. 1 student-led the procedure without allowing the peer(no.2) to imitate. Accordingly, the objective of demonstrating mainly lies in making the peer understand the process and not necessarily in imitation of the other.

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Assisting

'Assisting' denoted providing aid in the procedural implementation of a peer.

> F2: Now, I will place the solar altitude meter like this …. Then, let's turn on the lamps at the same time. Please turn on the lamp!
> F1: Okay (turns on the lamp).
> F2: This one makes a sound. Does that one make a sound, too?
> F1: Yeah, this one makes the sound, as well.
> <Procedure 3; Team F main experiment>

As demonstrated, the student(F1) assisted when the peer(F2) needed help or asked for help, such as executing according to the instruction of the peer to turn the lamp on and off and plugging it for the peer because s/he is closer to the outlet than the peer. 'Assisting' saved the time and efforts of the peer. It also enabled the peer to quickly perform the experimental activity. Meanwhile, 'assisting' was in contrast with 'demonstrating.' Although 'assisting' provided supplementary support for the procedure that could be fully implemented by the peer, 'demonstrating' intended to make the peer understand by personally taking action to demonstrate the procedure that the peer was unable to independently implement.

Monitoring

'Monitoring' refers to inspecting or evaluating the status by paying attention to the understanding or implementation of the procedure by the peer. In other words, it helps retain an adequate status to enable the peer to reach the goal. This process typically features a metacognitive characteristic.

> A2: I will do this… in this way (adjust the distance by placing the lamp far from the solar panel)
> A1: Hmm … (points to the two lamps and the solar panel) I think there's a bit of difference between here and there …
> A2: Ah — If so, how about this? (moving one lamp a bit further)
> A1: 20 cm is closer than we think.
> <Procedure 2; Team A main experiment >

For instance, the process included inspecting whether the distance between the two lamps and the solar panel set by the peer was maintained consistently and verifying the difference in the angles of the two lamps and the solar panel. Through the 'monitoring,' students observed the peer's understanding of procedural understanding or implementation of the experiment. Then one confirmed the fulfillment or non-fulfillment of each procedure of the other colleague's work by evaluating the results based on one's model for the experimental activity. Such 'monitoring' signaled the appropriateness of relevant procedural handling and enabled one to proceed to the next step. Moreover, 'monitoring' included providing sufficient time for handling the procedure, such as waiting and watching the peer.

Posing

'Posing' facilitated as the mean one posed a question deliberately to the other peer. Introducing challenging questions that required metacognitive processing and opposing viewpoints, this means enabled the peer to clarify one's thoughts and inspected the implementation.

> B2: (Reading the experimental procedure) Next, attach each solar altitude meter to the lab table beside the solar panel.
> B1: How do you think you should attach them?
> B2: Solar altitude meter on the lab table …. Wouldn't it be okay to attach it … (attaching the solar altitude meter on top of the solar panel) like this?
> B1: If so, why would you need this (solar altitude meter)?
> B2: Um …I am not sure…
> <Procedure 3; Team B main experiment >

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Similar to the aforementioned case, asking about the installation of the solar altitude meter during the experimental activity and the need for doing so or questioning how to vary the tilted degree of the two lamps were information that cannot be gained from the experiment manual. They were the essential factors to the effective operation of the experimental activity. Such 'posing' helped the accurate procedural processing of the peer and offered a chance for in-depth thoughts by clarifying the focus of thinking. 'Posing' questions appeared as the means of introducing new ideas or concepts.

Questioning

'Questioning' operated to asking curious concerns to the peer.

> A1: Why do the manual instructions maintain the distance between the two solar panels as 30 cm?
> <Procedure 1; Team A main experiment >

> C1: Do you know how to use this (solar altitude meter)?
> <Procedure 1; Team C main experiment >

As demonstrated by the narrative above, 'questioning' pertained to asking questions about aspects that aroused curiosity during the experimental activity. 'Questioning' appeared in contrast with 'posing.' If 'posing' intended to help the peer to conduct a more effective procedural processing or learning based on the model, then 'questioning' referred to asking curious concerns to structure one's model for the experimental activity in a more elaborate manner.

Explaining

'Explaining' intends to provide information to the peer by explaining or comparing an experience, idea, concept, and situation in detail.

> C1: No sound is made when you connect the solar panel and the buzzer by the same magnetic pole.
> <Procedure 1; Team C main experiment >

> D1: When you shine the light on the solar panel, the buzzer makes a sound; it makes a louder noise when the intensity of light is stronger.
> <Procedure 1; Team D main experiment >

As indicated in the narratives above, 'explaining' denoted offering information about the experience in terms of the methods or results of the procedure. 'Explaining' was chiefly exhibited when the peer was asking a question when one discovered a situation in which the peer required information during 'monitoring,' and when one was 'demonstrating.' In addition, 'explaining' provided information based on the model for the experimental activity and explicitly conveyed it or used various formats of analogy, hints, and examples.

Suggesting

'Suggesting' denotes the relay of unverified ideas and hypotheses to the peer.

> E1: It says here (experiment manual) to turn on the lamps at the same time. Don't you think this means that we have to turn on and off the lamps at the same time to control the variable?
> E2: Oh, that's right.
> E1: If so, since the temperatures differed earlier, let's take a short break and then try turning it on and off at the same time again.
> <Procedure 6; Team E main experiment >

The text suggested the conveyance of one's opinion concerning problem-solving. The information provided

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through 'suggesting' generated an opinion based on an inelaborate and incomplete model for the experimental activity. Thus, it was less trusted than the information provided through 'explaining.'

Types of Peer Scaffolding Exhibited by the Scientific Experimental Activity

Peer scaffolding in this study was significant in terms of their characteristics according to small groups. This research classified the types of peer scaffolding based on the characteristics of each case and inferred the patterns of peer scaffolding and the personal objectives demonstrated from each kind. By analyzing peer scaffolding per case, the concept could be organized into three types: task completion- scaffolding, task model elaboration- scaffolding, and learning support-related scaffolding.

Task Completion-Oriented Scaffolding: Teams A, D, and G

The objective of 'task completion-oriented scaffolding' is to accurately complete a given task with a peer. The following conversation demonstrated this type of scaffolding implemented during procedure 3.

G1: It says 20 cm, so let's do it like this, and then what was the next instruction?
Then I need to attach each altitude meter to the lab table beside the solar panel.
G2: Is this the altitude meter?
G1: Yeah.
It is written here that it is a solar altimeter.
G2: Besides the solar panel …. It is this one (points to the solar altitude meter), right?
G1: Yeah.
G2: I need to attach each to the lab table …. Is this supposed to stick?
G1: Yeah, you can stick it with a suction plate underneath.
G2: Oh, it sticks well?

<Procedure 3; Team G main experiment>

G1 demonstrated the arrangement of the electric circuit on the lab table to G2 and explained the action, whereas G2 performed the procedure after seeing and following G1's action. In this manner, the main means of peer scaffolding under these types are 'demonstrating' and 'explaining.' Students' behaviors that mainly appeared during the scientific experimental activities were significant in relation to the task completion, that was, processing of the experimental procedure. Therefore, the details of the explanation were primarily manifested as information about the procedure and materials. This was because the team focused on understanding and implementing the experimental procedure.

Moreover, 'monitoring' was occasionally identified as the means of peer scaffolding because a student without experience in the experimental activity needed additional time to understand the procedure.

A1: Should we turn it on at the count of three?
A2: Turn it on.
A1: One, two, three! (Turns on the lamp)
A2: Oh …. What happened? No, turn it off again.
Let's try after reading this (look at the experiment manual).

<Procedure 3; Team A main experiment>

D1: First, let's connect the solar panel and the buzzer with electric wire.
D2: And here, the solar panel and the buzzer must be connected by the same magnetic pole.
Oh! Is this the buzzer?
D1: I think I did it with two electric wires, one for each, earlier.
D2: Oh~ Okay. And then …

<Procedure 1; Team D main experiment>

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In team A's case, because A1 took the lead in implementing the experimental activity, A2 could not fully understand the experimental procedure. Therefore, A2 demanded that A1 pause the implementation and have the time to read and understand the procedure. Thereafter, A1 conducted 'monitoring' by waiting and inspecting the procedural understanding requested by A2. In the case of team D, D1 provided D2 with ample time even without D2's request and inspected procedural understanding by 'monitoring' to allow D2 to read and understand the procedure. The introduced two cases indicate that the understanding of the peer about the procedure should precede the performance of the experimental activity with the peer. For this objective, sufficient time for understanding the procedure should be provided. Without such an opportunity, the student without experience may find it difficult to construct a model for the experimental activity. A detailed explanation does not always lead to better learning outcomes. Rather than that, they pointed out that helping the learner independently understand the learning content is more important than providing an explanation. Thus, allowing understanding the experimental procedure of the scientific experimental activity to peers without experience with the activity would be a crucial experience that could lead the peers to be able to construct the structures of the experimental activity model, thereby promoting subsequent learning.

As the experimental activity progressed, the students' models became gradually elaborated. Hence, the level of the models for the experimental activity held by the two students in a pair slowly became similar. Accordingly, in the latter part of the activity, the means of scaffolding changed into complex ones, such as 'assisting,' 'questioning,' and 'suggesting.' Simply put, they mutually shared the responsibility of the given task in terms of achieving the purpose of accurately completing the task.

The following vignettes are parts from the thinking aloud material, conversation about the experiment, and the post-interview material during the preliminary experiment, which pertains to A1's implementation of procedure 5.

A1: Let's compare the sound volume.
A1: If it is difficult to compare, then reduce the brightness of the lamp ….
A1: Let's turn it on.
A1: I think this one (points to one buzzer) is a bit louder?
Let's turn it off now and ….

<Procedure 5; A1 preliminary experiment>

A1: One, two, three!
A2: This one is louder.
A1: This one here is louder? I had opposite results earlier ….
A2: Really?
A1: This one does seem a bit louder ….
A2: But this one is louder?
A1: Then, should we go with this one being louder?

<Procedure 5; Team A main experiment>

A1: Since the result differed from the previous one, it seemed there was an error in the experiment. So, I thought I had made a mistake. That's why I tried to once again check if the solar panel had been moved or tried to listen closer by moving around to see if the sound was being properly made.

<Interview with A1>

The results of the preliminary experiment and the main experiment of A1 differed from each other. For this reason, A1 discussed with the peer the outcomes of the main experiment. A1 expressed a lack of confidence in the outcomes through vague responses, such as "should we go with this one being louder?" After that, A1's peer scaffolding patterns changed from 'demonstrating' and 'explaining' to using complex means. In this sense, the cause of the 'task completion-oriented scaffolding' type seems to appear due to the incomplete model used in the experimental activity by the student with prior experience.

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Model Elaboration-Oriented Scaffolding: Teams C and E

The 'model elaboration-oriented scaffolding' type aims to elaborate one's model for the experimental activity. This type of scaffolding does not focus on the learning of the peer but on accurately completing the task by resolving one's curiosity about the experimental activity earlier and, therefore, elaborating on the incomplete model. Team C's conversation in implementing procedure 2 presents this aspect.

C1: These two (two solar panels) are supposed to have temperature differences.
C2: That's right.
C1: So, we shouldn't shed light only on one side.
C2: Ah — you're right.
C1: To make the variables the same, we have to first ….
Should we try doing this (moving the lamp) for this one first? Like this ….
The distance between this one (solar panel) and this one (lamp) must be 20 cm.
C2: Oh, 20 cm.
C1: But while they need to be the same 20 cm, you make one angle big like this. Make it almost 90 degrees. Make the angle small for the other one. But it still needs to be the same 20 cm!
C2: Does cm measure from the lamp to here (solar panel)?
C1: Yeah, from the lamp to here (solar panel).
<Procedure 2; Team C main experiment>

C1 explained to C2 the process by personally demonstrating the adjustment of the angle and the distance between the lamp and the solar panel. C2 watched the way C1 showed. The main means of scaffolding used by C1 were 'demonstrating' and 'explaining.' The details of the focus of the explanation were around the information on the procedure and materials, which is similar to the early stage of the experiment in the group that belonged under the 'task completion-oriented scaffolding' type. Specifically, 'task completion-oriented scaffolding' frequently demonstrated 'monitoring,' in which the no. 1 students waited and inspected to help the other peer(no.2) understand the procedure. Conversely, this type of scaffolding did not provide the time the peer required to understand the procedure. As such, C1 lacked interest in the peer's understanding of the procedure and was unaware that the peer took the necessary time and effort to understand the procedure. Thus, C2 did not experience the experimental activity firsthand but was left to structure the model by merely seeing and hearing the demonstration and explaining that it was quickly conducted by C1. However, as C2 gradually participated passively and provided negative responses about the experimental experience in the follow-up interview, it seems C2 found that structuring a model was challenging to him/her.

C1: What should I do with this one (solar altitude meter)?
C1: 90 degrees? Um …. How could I use this?
C1: Um… I'm not sure how to use it, but…
C1: finding an accurate angle for this one doesn't seem to matter much. So, first, the one on the left has a small angle, and the one on the right has a big angle.
<Procedure 4; C1 preliminary experiment >

C1: What I thought while doing this earlier is that when you shine the light here, then a shadow on this stick… may produce an angle.
C2: Ah … It seems okay… I think that's right.
(omitted)
C1: Then, there's the hypothesis I set up earlier. The solar altimeter. Should we try it roughly to see if that was correct? If my idea was right?
(omitted)
C1: What I had thought earlier was right. The reason it didn't work when I tried the last time must have been because it was 90 degrees. If so, let's turn it off again.
<Procedure 1 to 4; Team C main experiment>

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C1: I said earlier that I explained to the peer after setting up a hypothesis. But it occurred to me that I wanted to try verifying the idea since I came up with it anyway. So, since I thought that the number that points to the end of the shadow along the length of the stick's shadow should mean the angle that illuminates the surface, I experimented with that briefly.

<Interview with C1>

C2: First, since I was only reading words while doing something, I didn't understand some parts very well. So, because I don't know what it is in the first place, it doesn't hit home with me, and I think they were read as mere letters to me.

<Interview with C2>

As C1 could not understand enough how to use the solar altitude meter in the preliminary experiment, C1 performed procedure four inaccurately. Immediately after starting the main experiment, C1 suggested a new option based on the previous experience to the other peer and implemented it according to the option. In this manner, 'suggesting' was also a frequently used means of scaffolding. The pattern of elaborating the model for the experimental activity in this type of peer scaffolding was due to the incomplete structure of the model constructed through the experimental activity in the previous experience, which was confirmed in the discourse above. In addition, the difference from the 'task completion-oriented scaffolding' was that the peer did not seek the time to understand the procedure or that the student could not monitor the peer.

Learning Support Scaffolding: Teams B and F

The objective of the 'learning support scaffolding' type was learning through the experience of the peer with the experimental activity. Thus, this type of scaffolding was considered the ideal type of peer scaffolding to achieve the purpose of the activity. The following example was the conversation by team B for implementing procedure 2.

B1: Now, we have to adjust the angle. How would you go to do that?
B2: I think I can do it with this one (solar altitude meter).
B1: That one? That one's not yet introduced in this step.
B2: You're right …. Hmm …. Make one large and make one small … Should I make this one large and this one small? (pointing to the lamps on both sides)
B1: Alright. Do you want to make this one large? (pointing to the lamp on one side)
B2: I think I can have a look at this photo first (experiment photo in the experiment manual) and make it similar.
B1: Right. Let's try it.
B2: To make it large, first, make the distance 20cm ….
But adjusting this to 20cm is …. Should I try to make the angle large like this?
B1: This angle … does not seem… that bad.

<Procedure 2; Team B main experiment>

B2 led the implementation after reading and understanding the experimental procedure. B1 monitored B2 and participated in the experiment from an assisting position. B1 provided ample time while inspecting the peer's understanding and implementation of the procedure. Moreover, through 'posing,' B1 helped the peer, who was experimenting for the first time, to recall an important matter that the peer had failed to consider. In this manner, the primary means of scaffolding used by the team were 'monitoring' and 'posing.'

B1: I'll try first. What you must pay attention to is apparently connecting the same magnetic poles and connecting the plus and minus poles with the same ones first.

(omitted)

B1: Haha, I'll connect the code for you.

(omitted)

B1: I'll turn on the lamp.

<Procedures 1 and 3; Team B main experiment>

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Earlier, B1 encouraged B2 to directly adjust the angle of the lamp and the solar panel, then to maintain the distance between the lamp and the solar panel at 20 cm. However, B1 did not wait for B2 to conduct unimportant procedures, such as connecting the electric circuit, connecting the lamp's code, and turning on the lamp. This seems that B1 implemented these tasks on behalf of B2, and this seems to imply that B1 distinguished the important and unimportant segments in the experimental activity and appropriately responded according to the level of importance. 'Assisting' was conducted in the scope of refraining from interrupting the peer's new learning as the peer already understood the procedure. In addition, 'assisting' was used for less important aspects of learning by determining the importance of the procedure. By contrast, 'monitoring' was used to allow the peer to independently conduct the important procedures.

The details for 'explaining' and 'posing' for this peer scaffolding type relatively required more meta-information on performance and information on the experimental activity compared with those for other cases, and the information on the procedure and materials was minimized. This would be due to the student who was aware that the peer would naturally acquire the information by handling the experimental procedure and experiencing the experimental activity. In this type of peer scaffolding, the student suitably used 'monitoring', 'posing', 'assisting', and 'explaining' for the experimental activity situations of the peer. By identifying the importance of each procedure, the student monitored the other peer in independently performing the important procedure and assisted with less experimental procedures or those that did not significantly help for learning. This type of peer scaffolding was superficially possible because the student with experience presented a high-level model in terms of processing the experimental activity. The peer scaffolding of a group with a high level of knowledge focused more on the parts wherein each other required some help instead of supporting the procedures. In addition, whether the students of this type acquired a high-level model for the experimental activity because of the preliminary experimental activities or due to the influence of their prior knowledge and experience remains unknown. However, that aspect is not in the scope of the study, the analysis concerning that aspect will not be dealt with in this study.

The aforementioned types of peer scaffolding observed during the experimental activity illustrated different objectives, means, and details of scaffolding (Table 1).

Table 1
The Types of Peer Scaffolding Observed During the Experimental Activity

Type	Purpose	Main means of scaffolding	Main details of explanation
'Task completion-oriented scaffolding'	Accurate completion of the experimental activity by collaborating with the peer	Early-stage: 'demonstrating', 'explaining', and 'monitoring' Latter stage: all means of scaffolding	Information on the procedure and materials
'Model elaboration-oriented scaffolding'	Elaboration of one's model for the experimental activity	'Demonstrating,' 'explaining,' and 'suggesting'	Information on the procedure and materials
'Learning support scaffolding'	Peer's learning	'Monitoring', 'posing', and 'assisting'	Meta information on procedural performance and information on the experimental activity

Furthermore, while the 'task completion-oriented scaffolding' and 'model elaboration-oriented scaffolding' mainly remained at the surface level of processing the procedure, such as understanding and implementing the experimental procedure, 'learning support scaffolding' seemed to have improved the outcomes of the peer compared with the other types of scaffolding by relatively addressing meta-information on procedural performance and information on the experimental activity that the peer was unable to obtain from the experiment manual.

The reason for this difference in the types of peer scaffolding was affected by the degree of the elaborateness of the model for the experimental activity structured during the preliminary experiment, that is, the level of the model for the experimental activity. Additionally, the 'task completion-oriented scaffolding' and the 'model elaboration-oriented scaffolding' types varied depending on whether sufficient time was provided for the peer to understand the procedure.

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Discussion

Many science educators have been keeping trying to construct students' science experiment activities out of the form of "following cooking recipes." This effort to increase the effectiveness of scientific experimental activities has increased students' interest in learning scientific reasoning and scientific inquiry methods during experimental activities (Hofstein & Lunetta, 2004; Lunetta et al., 2007), clarifying the objectives of experimental activities (Hodson, 1990; Hart et al. 2000), promoting cooperation (Land & Zembal-Saul, 2003) and enhancing an understanding of the nature of science (Lunetta et al., 2007). This approach sincerely focuses on what students want to gain from scientific experimental activities.

However, the ideal approach of these existing studies is somewhat different from the actual approach of scientific experimental activities in the school context. In many cases, students are struggling with the process of the laboratory manual, and teachers in the context focus on the students and their interaction while they possess different background knowledge and work together to accurately process the experimental manual (Högström et al., 2010) to reach the goal of the class. Improving the accuracy and effectiveness of the experimental manual processing is the prerequisite to achieving the goal of experimental activities. In this manner, this study sufficiently reflects the context of experimental activities in the school context, and through the reflection of the actual scientific experimental activities and research outcome about peer scaffolding occurrence, this study represents the high ecological validity. Through the results of this study, it was possible to reveal what kinds of interactions were occurring between students with different experiences in the context of actual experimental activities, and based on this, the way of effective guidance for students' experimental activities.

This study derived 'demonstrating', 'assisting', 'monitoring', 'posing', 'questioning', 'explaining', and 'suggesting' as means of peer scaffolding. Although this outcome differs from the means and types of peer scaffolding proposed by Van de Pol et al. (2010), Kim and Hannafin (2011), and Shin et al. (2020)'s studies, it is similar in a broad category in terms of providing scaffolding to peers. The means for scaffolding can be mainly classified into four categories: 'providing actions for imitation,' 'providing information related to the performance of the students', or 'providing information necessary for performance, which encourages students to solve problems independently without providing information on purpose' and 'demanding cognitive answers.' The types of peer scaffolding in this study could be considered to demonstrate the characteristics of scientific experimental activities.

The three types of peer scaffolding were derived, and the crucial factor in determining these types was the level of the model for the experimental activity previously structured by the student who provided scaffolding regarding specific tasks during the experimental activity. This model for the experimental activity consists not only of information about the experimental procedure and materials but also of complex and multidimensional information, such as meta information on procedural performance and the experimental activity. Among the three types of peer scaffolding derived from this study, 'learning support,' which is a desirable scaffolding type for supporting the peer's learning, was observed in only two out of the seven cases. This result largely differed from the general notion that obtaining prior experience with an experimental activity will enable one to help the peer's learning fully. The reason for this outcome is that the experience of a preliminary experimental activity is insufficient for structuring a high-level model for the experimental activity.

If so, why did the students fail to structure the model for the experimental activity through experience easily? The most commonly observed scene was where the students were preoccupied with handling the experimental procedure and materials during the activity. This phenomenon was shown clearly in studies on student-student interactions during experimental activities (Lehman, 1990; Högström et al., 2010; Wei et al., 2019). The reason underlying this phenomenon was that the students might have no choice but to follow the instructions of the experiment manual to complete the task due to the characteristics of experimental activities (Högström et al., 2010), and considerable cognitive endeavor was required to process experimental procedures (Kim & Hannafin, 2004). Students faced various information during an experimental activity. In other words, they encountered new experiment manuals, unfamiliar terms, new materials, new concepts, and numerous information irrelevant to the experiment during an experimental activity. Based on the given information, they had to identify and organize important ones and determine which ones required a high level of cognitive processing. Therefore, all cognitive resources were invested into processing the procedure (Johnstone, 1997). As a result, the abilities to observe the phenomenon and solve the problem become limited. Students concentrate on handling the procedure and focus more on completing the task instead of accomplishing a meaningful experimental activity (Rop, 1999; Kim & Hannafin, 2011). Thus, completing an experimental activity task is not enough to readily equip one with a high-level model for experimental activity.

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In this aspect, the focus should be placed on the reason for conducting an experimental activity. For an effective activity, the focus should be on the scientific notions provided by the experimental activity and the abilities that could be gained from the experience, and what type of experience procedures were handled was not as important (Högström et al., 2010). The concept that should be vitally learned from an experimental activity is a phenomenon that requires observation and scientific concepts. In other words, support from the experienced peer should be provided to reduce the cognitive load of the other peering in terms of handling the experimental procedure to enhance the effectiveness of peer scaffolding. In this manner, the peer should be allowed to concentrate more on the observable phenomenon.

Furthermore, why does a student with a low-level model for the experimental activity fail to provide effective peer scaffolding? As mentioned previously, an experimental activity demands a substantial cognitive-processing capacity. In addition, students need to observe the peer and monitor the current status beyond the handling of a simple experimental procedure during peer scaffolding. In addition, students should identify an emergent issue and select appropriate responses (Hannafin et al., 2003; Shin et al., 2020). The students must also understand the entire situation throughout the processes (Choi et al., 2005; Liu & Tsai, 2008). In short, peer scaffolding requires metacognitive processing that goes beyond the implementation of the experimental procedure. It disappeared as the effective peer scaffolding was difficult because the student with an incomplete model for the experimental activity used more cognitive capacity in handling the experimental procedure.

Based on this, this study recommends effective methods for teachers in providing instructions for scientific experimental activities. For effective scaffolding, it can be determined that teachers need a model for an experimental activity at a level that no longer distributes cognitive processing resources to the handling of the experimental procedure. Thus, it is necessary that teachers first acquire all information related to understanding and implementing the experimental procedure by conducting a prior experiment. The model for the activity can then be structured. Moreover, sufficient time to understand the experimental procedure should be provided for the students. A high-level model for the experimental activity is necessary to enable students to concentrate on the actual observable phenomenon. When students lack sufficient time, they may only focus on handling the experimental procedure and acquire a superficial understanding of the experimental activity. This tendency was identical to the suggestion by Lunetta et al. (2007), that is, the teacher and the peer needed to provide adequate time for the student to independently generate questions and structure knowledge for effective scientific activities. In sum, students should be supported to prevent them from feeling a cognitive burden to understand and implement the procedure so that they can exert significant cognitive efforts toward observing the phenomenon and inferring about the overall experimental activity.

Conclusions and Implications

This study analyzed peer scaffolding by collecting data on the behaviors and discourses between students with the experience of the experimental activity with their peers. For the data analysis, this study firstly derived the information about the model for the activity that the students built. From the data, the study examined per case to categorize the types of scaffolding, then identified the information provided and used means for peer scaffolding, which were. Through the research outcome, of this study, the characteristics of the types of peer scaffolding demonstrated by each case could be described to derive, and the factors that determined each type also gained. These findings provide implications for a deeper understanding of small-group experimental activities in school contexts and the operation of effective experimental activity.

The results indicate that the students used seven means of peer scaffolding: 'demonstrating', 'assisting', 'monitoring', 'posing', 'questioning', 'explaining', and 'suggesting'. Three types of peer scaffolding emerged: 'task completion-oriented scaffolding', 'model elaboration-oriented scaffolding', and 'learning support-oriented scaffolding'. Each type was varied in terms of objective, main mean, and details of explanation. Moreover, two factors influenced the determination of these types. The first was the level of the already possessed model from the experienced colleague in the scientific experimental activity, and the second was whether sufficient time was provided to enable the other peer with no experience to understand the experimental procedure.

For effective peer scaffolding, students need to possess a high level of an experimental activity model. The high-level experimental activity model would be implemented not only to process the procedure of the experiment but also the support the peer in the activity. In addition, to support the non-experienced peer's effective learning, the peers should be given sufficient time to understand and construct the experimental procedure independently.

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Furthermore, the non-experienced peers should be supported by experienced peers in terms of reducing the cognitive load required in handling the experimental procedure and so allow them to concentrate on observation rather than implementation. In a scientific experimental activity, new information is imported from time to time, and, consequently, substantial cognitive resources are used in handling the experimental procedure; therefore, building a model for a high-level experimental activity is not a simple and easy task to achieve.

In this study, 7 cases of Korean university students' activities were introduced and studied. Because this study is qualitative and targets a small number of participants, its possibility for generalization is insufficient. Moreover, although the effort was made to describe the results outside the special situation of this experimental task of the study, the results may vary according to the context created by specific experimental activities. In this study, peer interactions in the context of scientific experimental activities in the school context were analyzed in-depth to provide implications for what kinds of scaffolding should be provided to students in terms of operating actual scientific experimental activities. The findings of this study demonstrate the importance of peer scaffolding to assist the students' effective learning and the role of teachers in scientific experimental activities. In addition to this, the model for the experimental activity designed and conducted in this study is deemed useful for explaining numerous constructs related to scientific experimental activities, such as the handling process and outcomes of the activity and the behaviors and cognitive processes of students. The research outcome would impact those pre-service and in-service teachers who want to design and implement their science classes to be more active and participative. The insights suggested in this study also assist the teachers' and researchers' epistemological stance on science teaching and learning as a rather active one – not the lecture-oriented subject. Additional studies are required to further subdivide the various aspects suggested in this study. An investigation of the level of influence of each factor also will be required.

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Appendixes

Appendix 1: The Experimental Manual Translated into English

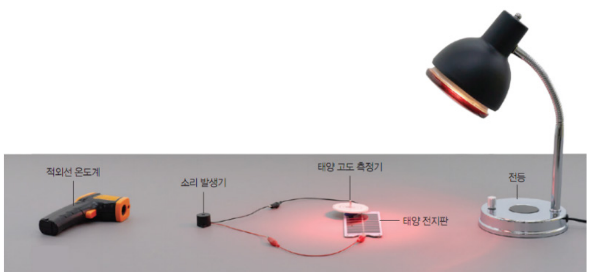
Determining temperature changes according to the meridian altitude of the sun

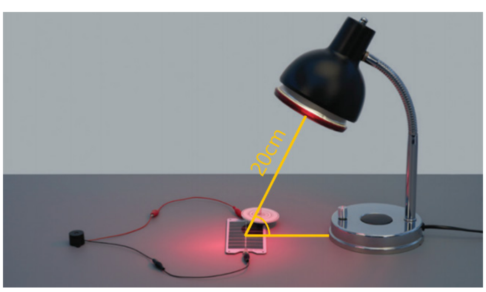
Materials

2 solar panels, 2 solar altitude meters, 2 buzzers, 4 electric wires,
2 lamp, tape measure, infrared thermometer

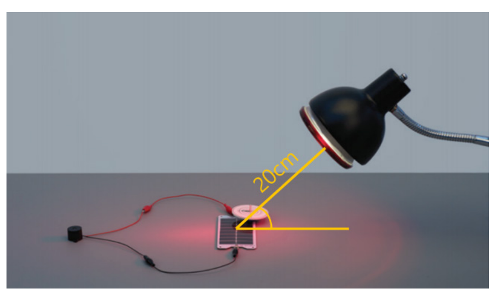
Procedures

1. Place two solar panels approximately 30 m apart on the surface and connect the buzzer and solar panels. Both materials must be connected using the same magnetic pole.
2. Install the lamp by placing the lamp and the solar panel at large angles, and the other one at small angles. Adjust the lamp to place 20 cm between the lamp and the solar panel.
3. Attach each solar altitude meter to the lab table beside the solar panel and turn on the lamps at the same time.
4. Compare the angle of the lamp and the solar panel using the solar altitude meter.
5. Compare the loudness of the sound from the buzzer according to the angles of the lamp and solar panel. If comparing the loudness is difficult, then reduce the brightness of two lamps and compare the loudness.
6. Turn off the lamp and measure and compare the temperature of the solar panel using an infrared thermometer.
7. Discuss what objects are being represented by the lamp and the angles of the lamp and solar panel.
8. Based on the results, explain why temperature changes depending on the meridian altitude of the sun.





When the angle made by the lamp and the solar panel is large



When the angle made by the lamp and the solar panel is small

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Appendix 2: Information Comprising the Model for the Experimental Activity

Category	Information	Explanation	Example
Information on procedure	Meaning of procedure	Meaning of the sentence in the procedure and the terms presented in the procedure	“The angle of the lamp and the solar panel refers to this angle (pointing the hand toward the end of the lamp while laying the hand on the surface next to the solar panel)”
	How to perform the procedure	Information on how to perform the procedure	“Connecting the solar panel and buzzer using the same magnetic pole means we have to check the + and − of the two materials and connect the same colors”
	Results showed when performing the procedure	Information on the results that will be produced when performing the procedure	“The temperatures of the solar panels are 22.6 ℃ and 42.9 ℃. Why do they differ so much? This is completely different from the previous result.”
Meta information procedure performance	How to efficiently process the procedure	Information on how to understand or execute the procedure more easily and quickly	“Differing the angle of the solar panel and buzzer is much easier if you refer to the picture.”
	Importance of the procedure	Information on the relative importance of each procedure in the entire experimental manual	“Shouldn’t we move (the distance between the lamp and the solar panel) 20cm further apart?” “Um, I don’t think this is right, (the distance between the lamp and the solar panel) falls a bit short here.” -> Repetitively inspects the important performance results of the procedure
	The difficulty of the procedure	Information on time and effort required to understand or execute the procedure	“Because I did not understand this part (how to use the sun altitude meter) and felt lost, I thought it would be hard for my colleague to do this alone.”
	Reason for performing the procedure	Information on why the procedure needs to be performed	“I think the reason for setting the distance between the solar panels as approximately 30 cm is because the buzzer of the solar panel on the other side can make sound due to the heat of the lamp on one side.”
Information on materials	Name and shape of materials	Names of the given materials and each part, the shapes and structure of materials	“The square one is the solar panel. Behind it is the electric wire of +, −.”
	How to use the materials	Information on how to use the given materials	“For the tape measure, you can press this middle part and then remove your hand and it won’t go back in again.”
	Operational forms of materials	Information on what kind of appearance the given materials operate with	“When the solar panel and the buzzer are properly connected and you hit the light, the sound is made from here (buzzer). Let’s try until the sound comes out well.”
	Use of materials	Information on why the given materials are needed	“The reason you need a solar panel is that different sounds are made depending on the amount of light.”
Information on the experimental activity	The overall process of the experimental activity	Overall information on pre-and post-sequence relation of all procedures of the experimental activity	“Not now (measuring the distance between the solar panels) but we need the tapeline again later for measuring the distance between the lamp and the solar panel.”
	The goal of experimental activity	Information on what needs to be achieved or acquired through the experimental activity	“It is to find out how the temperature changes according to the angle of the lamp and the solar panel.”
	Manipulation and control of variables	Information on the types and methods of variables that need to be manipulated or controlled in the experimental activity	“To control the variables of the experiment, you need to turn the lamp on and off at the same time.”
	Related scientific concepts	Information on scientific concepts that are learned through the experimental activity	“The summer with a high solar meridian altitude has a higher temperature than the winter with a low meridian altitude.”

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