Journal of Natural Disaster Science, Volume 38, Number 1, 2017, pp01-15

Disaster Education Based on Legitimate Peripheral Participation Theory: A New Model of Disaster Science Communication

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(Received: Oct. 24, 2016 Accepted: Dec.16, 2016)

Abstract

It is often suggested that disaster education should not be a one-way knowledge transfer from disaster experts to non-experts, but a bilateral interaction between the two sides. In this study, the authors propose a new framework for disaster education based on legitimate peripheral participation (LPP) theory, in which disaster experts and non-experts interact very closely to remove the barriers between the two sides. Specifically, the present study introduces two practical research methods for disaster education. The first is an attempt to convert a seismological observatory into a disaster science museum with collaboration between seismologists (experts) and volunteer staff (non-experts). The second is an endeavor to involve elementary school children in cutting-edge seismological research by installing a miniature seismometer at their school. As a result, volunteer staff at the museum formed a new identity in joint practice as semi-experts who mediate between experts and non-experts. Although the schoolchildren did not reach a definite stage as successfully as did the volunteer workers in the museum project, through this research, both the seismologists and the children realized what they had not shared, and this marked a starting point for further risk communication. The results are discussed from the perspective of LPP theory.

Keywords: disaster education, legitimate peripheral participation, community of practice, earthquake

1. Introduction

Recent natural disaster research suggests the growing importance of the role of non-experts in disaster prevention activities. This paper analyzes the relationship between experts and non-experts during disaster prevention-related activities, with a particular focus on disaster education. The first purpose of this research is to postulate that, in these situations, knowledge transfer is not central to learning, but that the relationship formed between experts and non-experts constitutes learning in itself that can be interpreted as disaster education. Consequently, this paper evaluates the effectiveness of learning that occurs among experts and non-experts in environments where purposeful interaction on the topic of disaster preparedness is introduced. The second purpose of this research is to evaluate the effectiveness of this type of disaster education where knowledge transfer is not central.

After a number of recent major catastrophic natural disasters in Japan, including the Great Hansin Awaji Earthquake in 1995 and the Great East Japan Earthquake in 2011, we often hear statements such as "modern high-tech structures in Japan were thought to be undamageable by earthquakes, but the idea that an elevated highway cannot collapse is a 'safety myth'," and "seismologists try to make excuses by saying

the size of the tsunami was totally 'unexpected'" (as examples, see *The Japan Times*, 2004; Okada et al., 2011; and Nogami & Yoshida, 2014).

The terms "unexpectedness" and "safety myth" have one important aspect in common, that is, an obvious lack of mutual communication and understanding between disaster experts and non-experts. Such phrases do not simply point to certain failures/defects in disaster science/technology in itself, but to the fact that experts have not successfully communicated with ordinary people about the limits and outcomes of their research.

For example, Kumamoto (2011) indicated that, even before 2011, some seismologists warned of the possibility, albeit very slight, of an unprecedentedly large tsunami in the Tohoku region based on research on the Jogan Earthquake in 869 CE. However, this warning was not taken very seriously in the academic or governmental sector. As a result, the warning was not widely communicated to non-experts. This poor risk communication generated a feeling of "unexpectedness" and "unknownness" in the aftermath of the Great East Japan Earthquake; however, in reality, the tsunami was not unexpectedly or unprecedentedly massive.

2. Previous studies

Before the Great Hanshin Awaji Earthquake of 1995, disaster prevention in Japan had mostly been based on hard engineering solutions. However, following this disaster, the importance of people-based approaches and risk communication became widely recognized in Japan, and many actions were taken in that area. Disaster education is one of the areas that came to prominence at the time as a people-based approach.

Disaster education is closely related to disaster risk communication. Risk communication theory suggests a gap between experts and non-experts in which experts try to transfer knowledge to non-experts, but these non-experts show indifference or pessimistic attitudes (Yamori, 2007). Shiroshita (2011) demonstrated that a communication gap exists among experts as well. The uncertainty created by these misunderstandings can lead to unforeseen and sometimes disastrous outcomes.

The problem pointed out by Yamori (2007) and Shiroshita (2011) in disaster education is known as the "deficiency model" in science communication theory. The "deficiency model" assumes "experts to be on the side of scientific knowledge and the general public to be on the side of no scientific knowledge, that is, on the side that is deficient in scientific knowledge. Information is assumed to be transmitted from experts with scientific knowledge to citizens with a lack of scientific knowledge" (Fujigaki, 2007). Figure 1 illustrates the deficiency model.

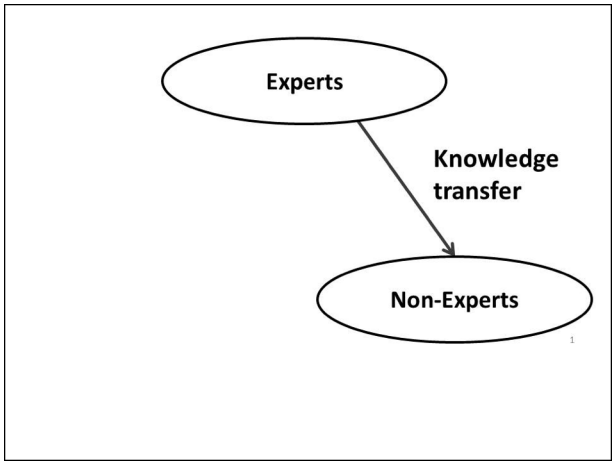

Fig. 1. Deficiency model

3. Use of legitimate peripheral participation (LPP) theory

This paper uses LPP theory to explain how learning occurs among participants who do not interact with the specific purpose of knowledge transfer, but rather with the purpose of learning sharing and information exchange. In LPP theory, learning is formulated as "legitimate peripheral participation in a community of practice." From this definition, we introduce technical terms and the relationship between participants in the learning process. As shown in Figure 2, in the "community of practice," full participants and new participants, both of whom are categorized as peripheral participants, maintain mutual negotiation on the basis of a central practice.

LPP theory interprets learning as identity building of each participant rather than knowledge transfer between the two. Building an identity consists of negotiating the meaning of our membership experiences in the community of practice.

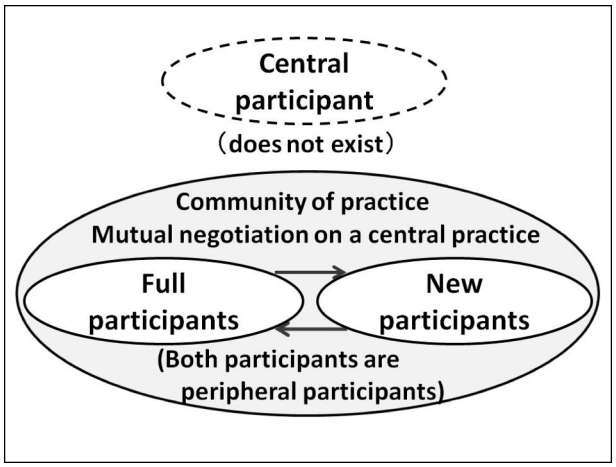

Fig. 2. Model of learning based on legitimate peripheral participation (LPP) theory

3.1. LPP

(1) Theory

Lave et al. (1991) first proposed LPP theory, which assumes that the essence of learning is LPP in a community of practice.

An explanation of the technical terms in LPP theory is as follows: "Community of practice" is a group of people involved in a specific practice; "legitimate peripheral participation" refers to an "authentic practice" of a community of practice in a plural and diverse way that is possible to perform, and the changing of the relationship itself with the passing of time. Here, the word "legitimate" means "authentic," "peripheral" means "plural" and "diverse," and "participation" literally means "participation" that is concretely performed.

These definitions are in accordance with Yamori's (2012) interpretation. In the present study, we revised the theory according to the definitions in the following paragraphs.

(2) Conditions of LPP

In this section, we consider the three conditions—legitimate, peripheral, and participation—for realizing LPP. These three conditions can be integrated into the following two parts: "legitimate and peripheral" and "participation."

The condition "legitimate and peripheral" means that there is a community of practice whose "authentic" practice involves a "diverse" form of participation by existing members. To put it another way, "legitimate and peripheral" means that a community of practice is "accessible." Shiroshita (2010) is correct

when he says that "'legitimacy' is the problem of whether or not there can be participation in a practice. 'Peripherality' is the problem of whether or not access is allowed to a valuable activity in the practice concerned." Legitimacy or what is regarded as "legitimate" is beyond the scope of our current discussion.

The other condition, "participation," means that each specific community of practice has active participants. It is easy to understand this condition because "participation" literally means participation. Here, we notice that the condition of "participation" is more concrete than the condition of "accessible," which is very abstract. Shiroshita goes on to say that "and if it is guaranteed and participation is done in a community of practice, learning is generated in itself." What the passage makes clear at once is that two conditions, "participation" and "accessible," comprise learning in LPP.

It follows that, to realize LPP, it is necessary that a community of practice be "accessible" and have active participants.

(3) Concept of "peripheral"

The concept "peripheral" means "diverse" or "plural." It is key to understanding LPP theory. It should be emphasized that it is a mistake to think of a dichotomy between "central" and "peripheral" in understanding the theory in terms of the plurality and diversity of "peripheral" in contrast with the unity symbolized by the concept of "central." The idea of "peripheral" represents diversity and plurality by subcategorizing various forms of "peripheral participation." Since all forms of existing participation are categorized as LPP according to the theory, the concept of "peripheral" represents a unity of the idea, in contrast to the plurality and diversity represented by its meaning.

We can represent the constitution of learning by setting a "central practice" in a community of practice. The term "central practice" can be defined as "a certain practice that is symbolic to a specific community of practice." We can set a central practice selectively from various practices that are observed in the community of practice, according to the focus of analysis. By doing so, we can analyze learning arising from LPP by a community of practice, whose central practice is not the transfer of knowledge and techniques that is generally regarded as learning.

After we select a central practice of a specific community of practice, any (legitimate) participation in the community of practice can be categorized as peripheral participation. Since the term "peripheral" means diverse, any possible (legitimate) participation in the community of practice can be interpreted as diverse participation.

Here, we have two distinct types of peripheral participants, namely, full participants and new participants. These two subcategories of peripheral participants are defined in a correlative way. According to the central practice specified, participants who have more experience become full participants. Conversely, people who have no experience, or at least less experience than full participants, become new participants. By subcategorizing these two kinds of participants, we can consider peripheral participation in itself, not in a way based on the commonly used binominal opposition of "central (participants)" and "peripheral (participants)."

All existing participants can be categorized as full or new participants. Future participants, who do not exist in the context of central practice at the time of the distinction between full participants and new participants, can be excluded from the subcategories. However, they may also participate in it in the future as new participants. Therefore, future participants may also be categorized as peripheral participants.

Various participants can be integrated into a united form of "peripheral participants." With such a categorization, a consistent view can be seen in analyzing a participation process that changes with the passage of time.

(4) Discourse of learning

The main point regarding the discourse of learning through LPP is continuous mutual negotiation between full and new participants mediated by a central practice, as shown in Figure 2.

According to Lave et al. (1991), continuous negotiation between the two participants causes three different kinds of change as the result of learning though LPP: new participants move toward becoming full participants, while full participants come to accept the "constructively naïve perspectives or questions" that

new participants bring in from outside the community of practice as "inexperience [that is] is an asset to be exploited." Acting as an intermediary between full and new participants, the community of practice itself changes.

3.2. Identity-building evaluation of learning

We are now ready to consider how to evaluate the results of learning engendered by LPP. We interpret the three results mentioned in the previous subsection as identity building by participants.

Lave et al. (1991) believe that participation in a community brings about self-awareness of becoming part of that community, as can be seen in the following quotation:

> Moving toward full participation in practice involves not just a greater commitment of time, intensified effort, more and broader responsibilities within the community, and more difficult and risky tasks, but, more significantly, an increasing sense of identity as a master practitioner.

This idea marks a clear contrast with the traditional idea that regards the results of learning to be the acquisition of knowledge and/or techniques.

Yamori (2012) has the following to say on the matter of identity building:

> We shall concentrate on the concept of "identity" stated by Lave and others. They use the word identity not in the narrow sense of personality or ego identity of individuals, but in the sense of the role or position that participants take in a community of practice. . . . The important point of learning is to obtain membership in a community in which participants act cooperatively.

Relevant to this point is Takagi's (1999) remark:

> In LPP theory, "to participate" corresponds to a situation in which the participant is in charge of a role of a certain practice accepted as legitimate in the community of practice. Therefore, we can interpret learning as a change in the way of participating, that is, a change in the role the participant takes in the community of practice.

From these remarks, one general point becomes very clear: The result of learning through LPP appears as a change in the role of the participant in a community of practice. We can understand the change in the role as the participant's change in identity. At the same time, the changes in role and identity are balanced by the change in the community of practice.

4. Case study

Theoretical assumptions are tested through case studies. Here, we introduce one scientific research project, the Manten Seismic Observation Project, and two field studies, the Abuyama Open Laboratory and a collaborative study program between an elementary school and the Manten Seismic Observation Project. Both case studies are characterized by the participation of non-experts in the practice of experts.

4.1. Abuyama Open Laboratory

The Abuyama Open Laboratory is an attempt to convert a seismological observatory into a disaster science museum with collaboration between seismologists (experts) and volunteer staff (non-experts).

The Abuyama Open Museum Project started in December 2010. The core members of the project are Yamori and Iio, who are Professors at the Abuyama Observatory, and a Planning Director at the Disaster Reduction and Human Renovation Institution. The Abuyama Open Museum Project aims to transform the Abuyama Observatory from a center of data collection for seismology into a museum of seismology open

to the general public.

During the startup period, the policy of the project was stated as follows: "When we think about the future of this observatory (building institute), it is the best decision to transform the observatory into a museum that mainly focuses on the history of seismology. With such a transformation, we believe that the observatory could be all the more valuable, in that it would be open to the general public, be a place to communicate with locals, and effect various types of learning, resulting in greater satisfaction by introducing numerous people to studies on seismology and other subjects related to the Abuyama Observatory."

Abuyama Open Laboratory is a series of events that were carried out based on such a policy. Abuyama Open Laboratory consists of two kinds of public events. One is monthly open houses, and the other is special seasonal open houses. The open house schedule is announced publicly, and citizens who wish to visit Abuyama Open Laboratory apply to participate in the event according to the schedule. In addition to a guided tour, several seminars or courses are arranged as part of the basic open house program according to the theme set each time such an event is held.

Abuyama Open Laboratory was held for the first time on April 3, 2011, not long after the Great East Japan Earthquake on March 11, 2011. The catastrophic disaster caused a certain unrest in Japanese society. This mood influenced the core members, making them hesitate about whether to hold the first special open house. Although they eventually decided to carry out the event on schedule, the scale of the event was reduced.

Abuyama Open Laboratory's second special open house was held on July 31, 2011. On this day, programs were arranged for children in the midst of their summer vacation and their parents. Since the programs were favorably received and successfully completed, core members began to consider Abuyama Open Laboratory more seriously.

The third special open house of Abuyama Open Laboratory was held on November 5, 2011. On this day, dialogical courses between core members and participants were arranged. The main themes of the dialogue set in the programs were the possibility of development of Abuyama Open Laboratory in the future. As a result of the dialogue, core members shared the common purpose of introducing volunteer supporters.

A volunteer supporter training course was arranged for June 2-3, 2012 as a special open house. On these two days, participants joined training programs necessary for leading a guided tour of the Abuyama Open Laboratory. For example, they studied old seismometers, the history of the observatory and Mt. Abuyama, and the accepted protocol for receiving guests. Participants who finished the training program were authorized as volunteer supporters.

The second volunteer supporter training course was arranged for October 20-21, 2012 as a special open house. On these two days, volunteer supporters who had continued training since the previous volunteer supporter training course practiced giving guided tours to visitors for the first time.

Hereafter, volunteer supporters began to lead guided tours of Abuyama Open Laboratory. In the 2013 academic year, volunteer supporters led 10 tours.

The third volunteer supporter training course was arranged for June 22-23, 2013 as a special open house. New volunteer supporters were recruited and participated in the training noted above.

Picture 1. Guided tour of the Abuyama Observatory for visitors by volunteer supporters

4.2. Manten Seismic Observation Project

The Manten Seismic Observation Project was an attempt to densely observe local inland earthquakes using hundreds of small seismometers. Iio's research group developed the latest version of the Manten seismometer in 2008. The Manten seismometer allows offline seismic observation. It consists of a velocity-type seismograph, a data logger, and a battery. The Manten seismometer is characterized by its power efficiency, which enables data to be recorded for up to about nine months. Another notable feature of the Manten seismometer is that many units of Manten seismometers are installed at the same time near each other, and so these are chosen for intensive observation of microearthquakes to clarify earthquake mechanisms.

The Manten seismometer is installed at the same time at many points in nearby areas, which are chosen to allow intensive observation of microearthquakes in order to clarify the mechanisms underlying earthquakes. For example, 82 observation points were set in the northern part of the Kinki area and 50 in western Tottori Prefecture; there are also observation points in eastern Shimane Prefecture, western Nagano Prefecture, the Nobi area, the Kyushu area, and New Zealand. As of July 2014, a total of 250 observation points using the Manten seismometer had been set to observe microearthquakes.

In Japanese, the word *manten* has two meanings that relate to the Manten Earthquake Recording Project. One meaning is "tens of thousands of points," which represents the ideal image of seismic observation. The other meaning is "perfect score," which means that the seismic observation project is (one of) the best ways to observe earthquakes.

4.3. Collaborative study program between an elementary school and the Manten Seismic Observation Project

A collaborative study program between an elementary school and the Manten Seismic Observation Project attempted to involve elementary school children in cutting-edge seismological research by placing a miniature seismometer in a school.

(1) Shimoyama Elementary School

Shimoyama Elementary School is located in the mountainous area of central Kyoto Prefecture. It has about 80 pupils (note: Japanese elementary schools have six grades).

A Manten seismometer was set up in Shimoyama Elementary School in 2009. Two motives combined to lead Yamori to install a seismometer at the school site. First, it would contribute to progress of the latest seismological research of the Manten Seismic Observation Project by adding another observation point. Second, it would enrich disaster education within the school and aid the shared practice of seismometer maintenance between experts and pupils.

After approval by the School Board, the plan to set up a Manten seismometer in Shimoyama Elementary School was realized on December 8, 2009. The actual work of installing the Manten seismometer was conducted by experts and pupils.

There is a network of Manten seismometers in the northern Kinki area. The Manten seismometer set up in Shimoyama Elementary School was a new observation point in the network. After the installation of the Manten seismometer, we continuously carried out disaster education. The class schedule was set as four times a year, in accordance with the timing of maintenance of the Manten seismometer. The classes consisted of seismometer maintenance by the pupils and the authors, and classroom lessons with themes related to the Manten seismometer and the Manten Earthquake Recording Project.

(2) Neu Elementary School

Neu Elementary School is located in a mountainous area of western Tottori Prefecture. It holds around 100 pupils. The Manten seismometer was set up in Neu Elementary School in 2010.

In 2000, the Western Tottori Earthquake occurred, striking Hino Town, where Neu Elementary School is located. It was around this area where damage from the earthquake was most extensive.

In 2010, the Tottori Prefectural Government planned a series of projects in accordance with the 10-year anniversary of the Western Tottori Earthquake. One of these projects aimed to promote disaster

education at Neu Elementary School. Neu Elementary School was selected because, first, Yamori was looking for a school in which he could carry out a disaster education project. Second, there is a connection between the Yamori and Tottori Prefectural Governments. Third, Neu Elementary School is located within the area of a network of Manten seismometers.

Iio planned to set a new seismometer at the site of Neu Elementary School because it is located in a 50-square-kilometer area that already contained 50 observation points. However, according to firsthand observations, if a new Manten seismometer had been set up in that location, noise from a nearby railway, a national road, and a river would have been excessive. Therefore, a site two kilometers from the school was chosen as the installation point. On May 17, 2010, Iio and students from Neu Elementary School installed the Manten seismometer.

Neu Elementary School has disaster education study programs other than the one in collaboration with the Manten Seismic Observation Project. One of these is listening to experiences of the Western Tottori Earthquake from family members, locals, and volunteer staff who have worked on the revitalization of the region. Other examples include a presentation in a public disaster forum and an annual school recital about what they have learned through investigative learning. The Tottori Prefecture Board of Education evaluated these various types of disaster education and gave an official commendation to the school in 2011.

In both of these elementary schools, we continued the disaster education program after the installation of the Manten seismometer. The disaster education program consists of three or four classes a year. The purpose and practical significance of the program are as follows. First, in the study program, elementary school pupils handle the maintenance of the Manten seismometer, even though they are generally thought to be practicing disaster prevention activities. Second, it is becoming difficult for seismology experts to periodically look after the seismometers as they spread out from the center of research.

As of July 31, 2014, we had held 17 classes at Shimoyama Elementary School and 15 at Neu Elementary School. In this paper, we focus our attention on seven classes held in each elementary school in the period of 2011 and 2012. We briefly summarize these classes in the paragraphs that follow. Sentences in which the name of the elementary school is not clear represent activities that were commonly performed in both schools.

Classes were held four times a year and attended by sixth-grade students. The class schedules were arranged in accordance with seasonal maintenance of the Manten seismometers. Each class consisted of seismometer maintenance and classroom lessons. Maintenance of the Manten seismometers set in the elementary schools was performed by the pupils and the authors. Classroom lessons were held under themes related to the Manten seismometer and the Manten Earthquake Recording Project. The practical purpose of the classes was to have pupils get a proper feel for the role of an expert.

Picture 2. Maintenance of the Manten seismometer by pupils

The work of seismic observation was divided between the pupils and the experts as follows. The pupils were in charge of seismometer maintenance and the experts offered support. The experts, as usual, did the rest of work, which included reading the data of collected CompactFlash (CF) memory and evaluating underground structures by analyzing the data.

Now, let us look closely at the work of seismometer maintenance. Seismometer maintenance is divided into three procedures: "ending procedure for seismic observation," "exchanging batteries and CF card memories," and "restarting seismic observation." Every year, in both elementary schools, about 10 sixth-grade pupils participated in seismometer maintenance. Accordingly, the pupils were divided into three groups, with each group in charge of one of the three procedures mentioned above.

Examples of the study program are provided in the following paragraphs.

In 2011, the constitution of the study program was irregular in that it specially focused on the Great East Japan Earthquake, which occurred just before the start of the elementary school year and shocked Japanese society. In the first class of the year in May, the first author taught sixth-grade pupils about the Great East Japan Earthquake and how it related to the Manten Seismic Observation Project. In the second class in September, pupils made handicrafts of the seismometer using PET bottles. Through the handicrafts, they learned the basic mechanisms of the seismometer. In the third class in November, classes were held under the theme of the role of experts who lead the Manten Earthquake Recording Project, including how these roles relate to the pupil's role of seismometer maintenance. In the fourth class in February, a group of pupils and teachers from Shimoyama Elementary School visited Abuyama Observatory. Through this visit, they deepened the knowledge that they had acquired in previous classes. Neu Elementary School is far from Abuyama Observatory, so instead of visiting, these pupils performed group work involving the reading of waveform data. In this group work, waveform data collected from the Manten seismometer were printed, and pupils then distinguished the waveform data of earthquakes from those of noise such as vibrations of passing trains or strong rainfall.

In 2012, the constitution of the study program was basically the same as what it had been in the previous year. The only major change from the previous year is that, in 2012, the fourth class was an online class linking Neu Elementary School, Shimoyama Elementary School, and Abuyama Observatory through a teleconference system. We planned it specifically for Neu Elementary School because they could not visit the faraway Abuyama Observatory. Through this class, each elementary school and Abuyama Observatory shared information about their activities associated with the Manten Seismic Observation Project and the unique culture of each place, which allowed both the pupils and the staff of Abuyama Observatory to deepen their understanding of the study program.

5. Discussion

In the community of practice of Abuyama Open Laboratory, seismological experts (full participants) and volunteer supporters (new participants) maintained an ongoing mutual negotiation around guided tours of the observatory. This resulted in the volunteer supporters building up a new identity and letting the experts rediscover the fundamentals of their roles.

In the community of practice of the "study program in elementary schools in collaboration with the Manten Seismic Observation Project," an LPP analysis of the apparently passive attitude of the students identified a constructive meaning.

According to LPP theory, participating in a community of learning where knowledge transfer is not central to learning, an "ideal" central participant (**Fig. 5**) does not respond to an expert, as argued in the deficiency model of risk communication theory. In other words, the central participant is not negative towards learning. Participation in the "community of practice," where knowledge is shared rather than transmitted in one direction from experts to non-experts, becomes a catalyst for shared learning.

5.1. Change in identity of volunteer supporters

A change in identity among volunteer supporters resulting from learning through LPP appeared in the

following respect: the participants in Abuyama Open Laboratory took charge of the role of volunteer supporters in collaboration with the experts.

Now, let us look closely at the discourse of learning among volunteer supporters. To begin with, at first, as visitors, the participants attended a volunteer supporter training course until becoming qualified. Next, these volunteer supporters continued taking voluntary training accompanied by seismology experts in a guided tour of the observatory. The relationship between the volunteer supporters and the seismology experts corresponded to mutual negotiation (interaction) between new and full participants, as mentioned in Chapter 3. Finally, the volunteer supporters led guided tours of the observatory for visitors.

The volunteer supporters who were at first visitors made efforts to take on the role of "volunteer supporters" who are mainly in charge of leading guided tours for other visitors. The volunteer supporters, by performing this role while still somewhat new visitors, realized that the visitors' own learning gives meaning to the guided tour.

LPP theory can explain how the role of volunteer supporters in the Abuyama Open Laboratory came into existence through their participation. In LPP theory, the result of learning is evaluated as a participant's identity building; here, identity means the role or position in the community of practice. Correspondingly, it can be assumed that the visitors' participation in the community of practice at Abuyama Open Laboratory resulted in identity building as volunteer supporters by taking and performing this role.

It is helpful to describe the role of volunteer supporters in Abuyama Open Laboratory before moving on to analyze the learning process. Their main task was to lead a guided tour of Abuyama Observatory. The guided tour is a central practice of the community of practice of Abuyama Open Laboratory. Other related practices include event receptions, making teaching materials and event exhibits, cleaning, and participating in voluntary training for guided tours.

Some data show the presence and scale of the activities. All data are as of July 31, 2013. First, 15 volunteer supporters continuously participated in the Abuyama Open Laboratory after qualifying. These volunteer supporters included 12 males and three females. Most of them were between the age of 60 and 80 years, and were past retirement age. A total of 211 people participated as volunteer supporters.

An analysis of the mutual negotiation between the volunteers and the visitors (**Fig. 3**) shows that the volunteer supporters took their role as their identity, thus fulfilling two theoretical conditions of LPP, namely, that volunteer supporters exist and that the community of practice of Abuyama Open Laboratory is accessible to them. In demonstrating their expertise, the full participants have established their legitimacy. Here, we can also think plainly that the legitimacy of the full participants means they are generally regarded as experts in this society. To discuss legitimacy in its entirety is beyond the scope of this discussion, but we may say in this case study that both ways of thinking influenced the practice.

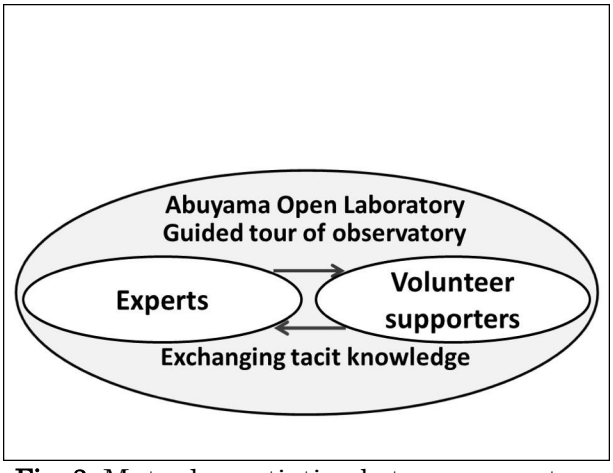

Fig. 3. Mutual negotiation between experts and volunteer supporters

From a practical standpoint, in order for a guided tour to function effectively, a certain important precondition should be met; namely, those acting as volunteer supporters need to carry out guided tours that consist of too many visitors for experts only to handle. Another important precondition is the arrival of laboratory visitors for guided tours that are led by volunteer supporters. Furthermore, it should be noted that the mutually dependent relationship between volunteer supporters and visitors can be changed through the participation process, because it is also possible for visitors to deepen their learning through maintaining participation in the Abuyama Open Laboratory and becoming new volunteer supporters.

This argument can be expanded into an analysis of the mutual negotiation between experts and visitors (**Fig. 4**). When volunteer supporters take part in voluntary training for guided tours, they receive a transfer of seismology knowledge from experts. Considering this relationship, we can find another aspect of the role of volunteer supporters, that is, volunteer supporters accept the knowledge of experts and pass it on to visitors. To realize this role, the existence of experts is necessary.

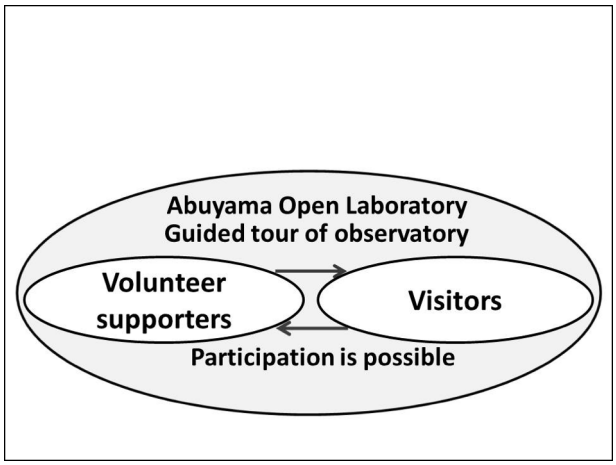

Fig. 4. Mutual negotiation between volunteer supporters and visitors

Focusing on mutual negotiation, it is at first sight a simple transfer of knowledge or techniques. In fact, the volunteer supporters had to not only accept knowledge of seismology from experts, but also look for what they needed to know or do in guided tours. This process is considered to be the sharing and exchanging of tacit knowledge. The term "tacit knowledge" is used in the sense that it is a kind of knowledge or technique with which one can perform a certain practice, although they are usually not conscious or have no clear perception of it (e.g., speaking or riding a bicycle).

For example, take the situation of voluntary training for guided tours. There were volunteer supporters, experts, and an old historical seismometer. In explaining the function of a pendulum in the seismometer, the experts used the term "natural period" (the period of one complete oscillation of a body or system) because they thought the meaning of the term was obvious. However, the volunteer supporters replied, "What is a natural period?" because they did not know this concept. In response to the question, the experts explained the natural period to the volunteer supporters. Later on, the volunteer supporters made a miniature pendulum, through which they explained the natural period to visitors in a guided tour.

They knew about the existence of a pendulum in the seismometer because they had participated in guided tours as visitors. But they did not know that the concept of the "natural period" was related to the function of the pendulum because they were not experts, and this idea is only common among experts. On the other hand, the experts understood "natural period," but they could not fully outline the concept to the volunteer supporters. The volunteer supporters learned something they had not previously known through mutual communication with the experts. Through learning about the existence of the concept of a natural period, the volunteer supporters knew what they did not know before and represented their understanding of the concept by making a miniature pendulum.

An example of tacit knowledge is the concept of a "natural period" that appeared in the mutual

communication between the experts and volunteer supporters mentioned above. The volunteer supporters found the concept of a natural period to be something they did not know, so they asked the experts.

By explicitly indicating tacit knowledge, the volunteer supporters got a chance to learn something new. At the same time, the volunteer supporters gained an opportunity to follow or copy remarks or behaviors from the experts' tacit knowledge. On the other hand, the experts had a chance to rethink a remark or behavior that they regarded as too common or natural to require any additional explanation. At the same time, they had the opportunity to reconsider and adjust remarks or behaviors underlying their own framework of knowledge as an expert in accordance with the needs of the volunteer supporters in leading a guided tour. In other words, they renewed the concept of a natural period through copying and arranging remarks or behaviors according to the needs of the visitors. To put it plainly, they learned with each other.

The situation above indicates that the volunteer supporters performed active learning through their role and identity by participating in the community of practice at Abuyama Open Laboratory.

This leads to a further consideration of mutual negotiation between experts and volunteer supporters. In the following section, we consider this relationship from an expert's point of view.

5.2. Change in identity of experts

In this section, we consider the change in identity of an expert (Iio). The first author interviewed Iio on January 24, 2013. The interview provided good evidence to show the change in identity.

According to the previously mentioned theoretical assumptions, we consider identity to be a result of change in which a full participant (Iio) comes to accept "constructively naïve perspectives or questions" that new participants (volunteer supporters) bring in from outside the community of practice of Abuyama Open Laboratory in the following form: "Inexperience is an asset to be exploited."

In the interview, the author asked Iio the following question:

Through conducting Abuyama Open Laboratory, has your view on your research changed?

Iio said to the author in response:

Even when explaining old seismometers that I no longer use for seismic observation, volunteer supporters often ask me questions about how the item relates to useful outputs. Such interactions make me feel that I have to output good results through my seismology research activities.

When I explain my research to people who are unfamiliar with it, I interpret it for myself beforehand because I have to confirm or understand basic knowledge again before explaining it to others. It is necessary for experts to repeatedly check basic knowledge that they usually regard as obvious, and to understand it again. Therefore, the Abuyama Open Laboratory gives me valuable and useful chances.

The author went on to ask to Iio:

Through conducting Abuyama Open Laboratory, have there been any changes in your self-perception?

Iio answered as follows:

My seismology work covers just a small area because seismology covers various fields and has been built on the culmination of predecessors' persistent efforts. Consequently, a lot of knowledge needs to be accumulated before understanding and proceeding with my research.

It is difficult to explain my research to the general public in cases such as Abuyama Open Laboratory or similar public lectures. Metaphorically speaking, let us suppose that my research is a stairway that has 10 steps. I assume that the general public understands only the first step because they don't have basic knowledge of seismology, so I start my explanation from the beginning level. On the other hand, I have to give my lecture within a specified time. By contrast, I can make experts understand all 10 steps because I

assume that they not only have basic knowledge, but also know up-to-date technical terms through continuous seismology research activities. However, I'm afraid that the stairway is cut off; that is to say, I don't think experts always have a clear understanding of basic seismology knowledge. Basic seismology knowledge and the latest technical terms are not always shared. I therefore think it is necessary for seismology experts, including myself, to review basic seismology knowledge usually regarded as obvious and to understand it again from time to time.

Considering the interview above, Iio's change in identity can be explained by LPP theory as follows: First, Iio, who is theoretically a full participant of the community of practice at Abuyama Open Laboratory, recognized new participants and gradually came to acknowledge them as volunteer supporters who were theoretically full participants. Second, Iio interacted with volunteer supporters concerning guided tours, which theoretically is a central practice of Abuyama Open Laboratory. Third, through this interaction, Iio confirmed his framework of seismological knowledge and rebalanced his behavior accordingly. He also rebalanced his behavior with the intentions of the volunteer supporters; namely, he refined his role in the community of practice at Abuyama Open Laboratory, which can be explained as a change in identity.

5.3. Change in identity of pupils

In this section, we consider the result of learning through the participation of pupils in the latest seismic observation project. It must first be acknowledged that changes in the identity of pupils emerged less clearly compared with the volunteer supporters in the Abuyama Open Laboratory.

First, as of July 2014, more than 100 pupils of the two previously mentioned elementary schools participated in the study program to practice seismometer maintenance, which lasted 4.5 years. While the facts above show that the study program allowed pupils to become involved in seismometer maintenance as an elementary part of seismic observation, it is hard to say whether the pupils refined their role in maintenance of the seismometer voluntarily or independently to improve seismic observation activities or improve their skills.

On the other hand, it is likely not far from the truth that the pupils were conscious of their role in seismometer maintenance because seismic observation was considered important. For example, such an attitude appears in the following remark: "We learned not to play around near the Manten seismometer in order to avoid having extra noises recorded by the machine." Their behavior in making a box covering and protecting the Manten seismometer is another example of the same point.

The most likely explanation is as follows. According to LPP theory, participating in a community of learning where knowledge transfer is not central to learning, an "ideal" central participant (**Fig. 5**) does not respond to an expert, as argued in the deficiency model of risk communication theory. In other words, the central participant is not opposed to learning. Participation in the "community of practice," where knowledge is shared rather than transmitted in one direction from experts to non-experts, becomes a catalyst for shared learning.

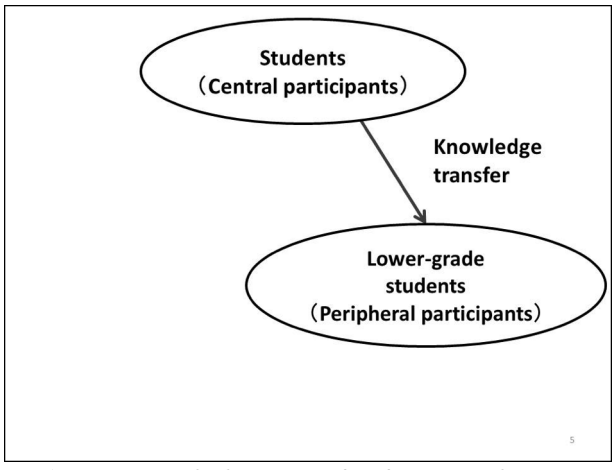

Fig. 5. Knowledge transfer from students to lower-grade students

This theoretical application could be significant for the following two reasons. First, it is possible to assume that ideal and abstract "central participants," based on the "deficiency model," are set against real and concrete "full participants," based on LPP theory, and this provides a continuous opportunity to induce dialogue or communication concerning what knowledge or techniques should be handed down because it is easier for new participants, who are new to LPP theory, to share the concept

of "central participant" than that of "full participant." Another possibility is that, from a theoretical perspective, the "deficiency model," which has a negative meaning, or is at least criticized in the context of science communication theory, took on a positive and constructive meaning in the context of LPP theory. Corresponding to the general concept of "expert," the concept of "central participant," which does not exist but can be thought of as an object, can be all the more important.

Regarding the practical importance of this theoretical application, even if certain knowledge is found to be valid and effective for disaster prevention activities, it is costly for the receiver to learn and master it. Therefore, it is reasonable to carefully consider whether to hand down the knowledge or technique before transmitting and diffusing it. From this, the "deficiency model" can be thought of as important for this discussion. Since what knowledge or technique to hand down could be a common precondition of discussion, any miscommunication could be potentially resolved by transferring knowledge and techniques.

In addition to the cost of transferring knowledge and techniques, this theoretical application could be effective in solving the problem of pessimism and optimism, as stated previously.

LPP theory should therefore be concluded to be a good platform for bridging the communication gap between experts and non-experts.

6. Conclusion

In the community of practice of Abuyama Open Laboratory, experts (full participants) and volunteer supporters (new participants) maintained ongoing mutual negotiations concerning guided tours of the observatory. This resulted in volunteer supporters taking on a new identity and experts rediscovering the fundamentals of their role.

In the community of practice of the collaborative study program between the elementary school and the Manten Seismic Observation Project, a constructive meaning was identified through an LPP analysis of the apparently passive attitude of the students. Rather than finding the deficiency model flawed as a cause of the communication gap, we found that it served as a communication bridge between experts and non-experts.

These findings suggest that LPP theory allows disaster education to be recognized and discussed in the context of a specific and substantive "community of practice."

Note

This manuscript is a revised version of the paper written in Japanese, which was published in the *Japanese Journal of Natural Disaster Science* vol. 34-2.

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