Situated learning in scientific practice: an ethnographic study

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Abstract
In this study, I will describe learning as the way of participation in communities of practice (Lave & Wenger, 1990; Wenger, 1998) by focusing on international graduate students (IGSs) in a science lab in Japan. I will show how IGSs are able or not able to access the machines necessary for research, by focusing on two European master's level IGSs: Karl and Max. In doing so, I will attempt to show how lab members' access to machines is socially organized. How one is able to access machines or not symbolically represents the member's way of participation in the lab practice as well. This report is part of a four-year ethnographic study in an applied physics lab at a large Japanese university.

Keywords
communities of practice, situated learning, access, scientific practice, participation

Introduction

In an experimental science lab, access to machines and other research equipment is very important for lab members because machines and equipment are indispensable for conducting research. Some of the machines and equipment are very delicate and they have to be handled with care. Furthermore, the operation of machines is complicated, and descriptions in manuals are often not detailed enough. The manuals are written for general users, but in labs, the use of machines is very specific. The informal manuals created by lab members and found in most if not all labs is evidence of this. However, one cannot describe all the details about how to operate these machines. Members in the lab help each other and learn from one another when they use machines. The knowledge of how to operate delicate and complicated machines is socially distributed. Also, since machines are shared in the lab, the use of machines is negotiated among users. This social management of machines is important in order to ensure that lab members treat machines properly. In other words, from the viewpoint of each member in a lab, access to machine is socially organized, and how one is able to access machines or not typically represents the member's way of participation in the lab practice.

In this paper, I will show two things. First of all, I will illustrate that access to lab practices is socially organized, by analyzing in detail how two IGSs were able or unable to access machines. By doing so, I will attempt to demonstrate how the access to machines in labs is social organized. This issue of access became visible by focusing on contrasting cases of IGSs. Second, I will show how participation in communities of practice is accomplished and organized through participation in multi-layered activities and situations.

In the following sections, I will describe how problems occurred and relate these problems to the ways of participation in a community of practice.

Background

This research was conducted in an applied physics lab at a large Japanese university. The data consist mainly of participant and non-participant observations, interviews, and e-mail documents. The main participants were Japanese government sponsored Europeans students. There were about 17 Japanese students and 4 IGSs, and 4 faculty members in the lab. (During the four and a half years of the research, students, post-doctoral fellows, and researchers came in and out of the lab, and thus the number of the lab members fluctuated.) There were two offices where the students, including the IGSs, had their desks lined up next to each other. Only the full professor had his own private office. Graduate students worked every day, and most of them spent extensive hours there. When I started the data collection, most of the time they appeared busy with research related activities such as making of samples, evaluating them, and analyzing them.

Karl' s Case: Failure to access the machine

Karl arrived in Japan as an exchange student. For awhile, Karl was working strange hours, like 4:00 to 8:00 in the morning,

because he needed to change an attachment on the machine he was using. While he changed the parts, others could not use the machine, so he did it at strange hours when no one was around. I said it was very considerate of him, but he replied, "I call it survival." His schedule was seen as odd by some Japanese students. One Japanese said Karl's behavior was anti-social. In fact, avoiding the need for communication was part of Karl's motivation for working at such odd hours.

Some Japanese students had been unhappy with Karl's use of the machine. The main user of the machine, Toshi, subsequently made a schedule for machine use and this made Karl's access to the machine almost impossible. Karl was upset by this. Eventually, he decided to conduct his experiments in another institute where he did not have to share a machine with anyone, even though he had to spend several hours commuting everyday.

I knew that Toshi was not very fond of English speakers, including me. Thus, when I heard this from Karl, it seemed that Toshi was trying to be mean and prevent Karl from using the machine. In fact, Toshi was trying to keep Karl away from the machine.This was a symbolic incident where Karl could not access machines, that is, how he could not participate in the lab's practice.

Toshi's account

On Karl's account, Toshi's conduct seemed like bullying. However, later interviews with Toshi and other Japanese students revealed different reasons than personal dislike. Toshi told me the importance of "trust". For him, the machine is his treasure, "tora no ko no soochi [my treasure machine]." Thus he did not want someone he could not trust to use his machine, as he elaborates below.

"If we are using the same machine, and if an international student breaks it, then I have to contact the maker of the machine, and try to fix as much as I can by myself. This will not make me feel good. [Whether this person is an international student or Japanese,] I do not want people who are not familiar with my machine to touch it."

Other students using the same delicate machine also expressed the same opinion independently, i.e. that they did not want unskilled or untrustworthy people to use the machines.

Once, Karl changed the angle of the mirror in the machine. Toshi was upset. However, Karl believed that this change in angle would improve the research. Karl told me that he had used a similar machine in his lab back in Europe and that he had made better focus (thus obtaining better results) by changing the angle. He continued that if one cannot reproduce the same results under the same conditions, it is not science. For him, changing the angle was not just for his own purposes, but also for the lab, and for better science; Toshi clearly did not share this opinion. Since Karl couldn't speak Japanese, at times like this, another IGS, Max, interpreted. Nevertheless, the problem was not solved and both sides continued to feel uncomfortable about the issue.

Along with my observations, the following interview with a Japanese student, Tamada, revealed yet another aspect of lab life and values.

Tamada's machine was old and really slow, so it took 4 hours to complete one part of his experiment. His friend Ida was using a newer and faster machine of the same kind, which took only 1.5 hours. Thus, Ida could do his experiments many times a day, whereas Tamada could do his 3 times at most. However, even when Ida's machine was free, Tamada would not use it, for fear of possibly affecting Ida's results.

If someone changes a setting, the regular user of that machine might not be able to reproduce the same result as before. Thus when someone asked Tamada to let him use new and different material, Tamada wanted to refuse if at all possible. After a new material has been used, there might be some residue in the chamber of the machine. Maybe this residue would influence his experiment, maybe not. Tamada sometimes washed and cleansed the wall of the chamber with chemicals to rinse off the unwanted substance, but it was also possible that having this extra unwanted substance would affect results favorably. This interview shows the fragility of the data they were dealing with. We tend to believe that science is very solid, and perhaps also the myth that if science is not reproducible, it is not science, as Karl said. However, it is well known among people who actually practice experimental science that even in the same lab, using the same settings, the results of a delicate experiment can be obtained only by someone skillful. According to my interviews with IGSs in other fields, this is true not only in applied physics, but also true in other fields like biotechnology or biochemistry.

Tamada also mentioned "trust" in the same interview. He and Ida were good friends, so he could let Ida use his machine to a certain extent, because he trusted him. Tamada was confident that Ida would never use a substance that would affect his own data.

Another important fact in the lab is that the data is cumulative. Lab members systematically design research and change parameter settings such as temperature, gas pressure, laser power, and distance. If someone interrupts this long series of experiments and changes some setting, all the data from the beginning of the series could be ruined. This could be the kind of data that one's sempai (senior) started the previous year, with extensive hours of engagement in the repeated processes of experiments.

Tamada described the use of machines by IGSs as follows:

They do not follow the details of the rules. Even if they are not supposed to turn the neji (screw) after a certain point, they do. I warned them several times, but it was turned too much. The machine might easily have broken. For example, take the

minute adjustment of AFM (atomic force magnifier). Once you turn it too much, the screw would become loose (thus broken forever).

Another student said about the use of machines, "It is impossible that everyone has the same level of mastery." However, they were required to share the machines, and thus they had to help each other. Some had more knowledge than the others, and the kinds of knowledge they possessed were complementary. Knowledge about the operation of machines was thus socially distributed.

We are dealing with a micro (meter) and nano (meter) world. Thus it is important to keep clean. We each have different tweezers for different purposes. The ones for the cleanest use, ones for sort of clean use, and ones for miscellaneous use. We wash them periodically, and we use sakuramen (a brand of disposable plastic gloves for science used in this lab). Even if nearly everyone uses clean tweezers cleanly, if there is one person who does not, it's no good.

This shows how the level of cleanliness is kept by everyone's daily effort and cooperation. The use of sakuramen and cleanliness was mentioned by another student from another lab in the interview. This person also mentioned that nationality does not matter.

Toshi said that Japanese students knew where other Japanese students were, so if one's experiment ended early, then they could adjust the schedule because they know who is where, and they could talk about problems of machine use. In contrast, Toshi said, he had no idea where IGSs were. In the case of Karl, Toshi did not even know why this person was in the lab, what kind of research he was conducting, or how long he was staying in the lab. Similar statements were heard from other Japanese students.

What Toshi said is related to social distribution of knowledge in the lab. For example, it is difficult to know the details of how to use a machine or current conditions if the person is not there. If here is a problem regarding one's use of the machine, they cannot help each other unless the person is available at that time.

Thus, Toshi's description above illuminates the knowledge ecology of the lab. This corresponds with the data reported by Stucky (in press) about copying engineers called "paper handlers". She describes how executives discovered the "knowledge ecosystem" of paper handlers by "core competency (i.e. paper handling) reconnaissance mission." She also describes paper handlers' technological knowledge of printers at Xerox as a social network that "was made up of various communities of technical expertise, linked by various people who knew someone who could answer the question, who knew the assistant's telephone number who knew that Frank always returned those calls in a timely fashion and made sure Frank knew Joe had called." (Stucky, in press.) This knowledge ecology exists applied physics labs in Japanese universities as well as in workplaces in the U.S..

Analysis

Karl's case illustrates how lab machines are socially organized. Because some machines are complex and delicate, and also shared, the lab members need to negotiate their ways of using the machines with other members. The lab members usually work in groups, and since the machines in the lab are shared by all the members, they must effectively negotiate their schedules. For some experiments, the experimenter needs to change the settings of a machine. Japanese students do not want other users to change the machine conditions, because by changing a setting and using the machine with different material, other people's data could be ruined.

Toshi not only used the machine heavily, but he also did the maintenance of the machine and made a schedule of use as a "gatekeeper" for machine access. Ida and other students told me that a heavy user of a particular machine also manages and fixes that machine. According to the Japanese students, it is very important for them to share machines only with someone whom they can trust, someone who is considerate enough not to influence or ruin other people's data.

Black-box

According to Wenger (1990), a black-box is an artifact whose cultural meaning is not transparent because one cannot access the activity where that artifact is utilized.
In the case of Karl, the machine was a black-box for him. This is because he could not access the machine and the social networks around the machine.

At the same time, the reason why Karl could not access the machine is due to his way of understanding the cultural meaning of machine. He thought that the machine was stable even if he changed the experimental condition substantially. That was quite different from Toshi and the other members' way of understanding the machine. From the view point of Toshi, Karl did not understand the delicateness of machine. Thus, Karl's way of understanding the cultural meaning of machine prevented him from accessing the machine, and without being able to access the machine, he could not have the opportunities to see the different cultural meaning of the machine in lab activities.

Karl's trouble of access to the machine is probably an exceptional case in the lab; however, because of its exceptionality, it well illustrates how access to machines is socially organized. If no one had the trouble Karl experienced , how access to machines is socially organized would not have become visible.

In this section, Karl's failure to access the machine was described. In the following section, another IGS who was

successful will be described as a contrasting case.

Successful access to machines: Max's case

Another IGS in the lab, Max, was successful in accessing the machines. Max knew where all the machines were, even though machines were in many different places on campus and even in different institutions off campus. How was it possible? Knowing what kinds of machines are available and where they are is a very important resource in lab life. This is because the type of research possible to conduct is restricted by the kinds of machines available in the lab.

What helped Max's access to machines was an informal network of master's level students. This was formed through participating in voluntary informal activities such as eating lunch and dinner together, and participating in the formal activities organized by the lab such as the summer trip. When Max went on the summer trip, Peter, another European IGS in S lab, said it was a stupid thing because he was convinced from his experience from the previous summer that the trip was a waste of time and money. He also thought that eating lunch and dinner together was a silly practice. However, right before Max went on the trip, Peter told me that Max, who had only been in the master's program for 4 months, already knew about all the experimental rooms, whereas it had taken Peter a full year to figure things out. Peter said, "After the summer trip, Max is in the center. He knows how to use the machines. He is really part of the group. ... now I can see. It is great." Peter was impressed by Max's informal network. By this first year M.S. students' informal network, Max could ask his peers about where machines were or how to use them. He could also arrange a car ride to an airport for other IGS's trip back home by asking Japanese students. Max became someone whom others could "trust." They mutually constructed a trustworthy relationship. Through participating in both formal and informal activities, his access to machines became possible.

Karl's case revisited

In this section, I will examine the background of Karl, how he could not access machines, and how he could not participate in the practice.

Karl started taking Japanese classes shortly after his arrival in Japan. He was eager to learn Japanese but he could not attend every class because of his experiment schedule. The textbook was written in kana [Japanese writing] and Karl soon realized that he was the only illiterate student in the class, and began to feel that he was wasting his time. He could not memorize all the kana characters. Moreover, there were kanji [Chinese characters] in the textbook even before he could master kana. He said he only wanted to learn conversation, but in order to learn conversational Japanese in class, he needed to be able to read Japanese to a certain extent. He wanted to study Japanese, but he could not continue. On the other hand, for many Japanese students in this lab, communicating in English was stressful. As one of them explained painfully about his difficulty in communicating with IGSs, "I have to communicate in my lower than junior high school level English."

Karl told me about the importance of human relationships in the lab. It is very important for members of a lab to work in a group in science in general, and S lab was not an exception. After almost 5 months into his stay in Japan, Karl told me jokingly, "I don't even know which group I belong to." This was consistent with what Japanese students said about Karl: they did not know why he was in the lab, what he was doing, or, how long he would be there. Karl was not happy that he did not have any Japanese friends in the lab, but he did not participate in daily and seasonal events.

Several IGSs have told me, echoing Peter, that they feel it is a waste of time and money to attend Japanese drinking parties or lab trips. Besides being expensive, Japanese drinking parties and lab trips are boring because IGSs do not understand what Japanese are talking about or laughing about. Meal gatherings are also painful for IGSs, because of time constraints, and the language barrier. One Japanese student said that the IGSs who fail to participate in drinking or meal gathering were not liked, because Japanese students feel that these IGSs only come to talk to them when they were in trouble.

Language alone wouldn't solve the problem

An episode of Max, the trusted interpreter, not being able to fix Karl and Toshi's problem, clearly shows language itself does not solve the problem. When Karl could not access to the machine in the lab, Max helped him as a Japanese-English interpreter to negotiate use of machine with Toshi. In this context, Max was working as a "broker" by being an interpreter. Wenger(1990) writes about brokering and in so doing refers to the work of Eckert (1989) as pursuing similar lines of thought. Wenger calls "use of multimember ship to transfer some element of one practice into another brokering." However, this attempt was not successful. This episode shows language alone did not enable Karl to access the machine, because the issue concerned more globally the way of participating in this community of practice. Karl's failure in machine access itself relates to his non-participation in the community of practice. We should also consider the fact that Karl's opportunities for interaction with other members (Japanese) the community of practice were extremely confined. He experienced disappointment at both his Japanese class and the level of Japanese students' English, and he withdrew himself from engagement in many interactions. Thus, Karl had only minimal opportunities that might enable him to participate in the community of practice.

On the other hand, Max had many opportunities to interact

with lab members to organize his participation in the community of practice. Max's improvement of Japanese is closely related to his way of participation in the community of practice. Max could access machines not only by his Japanese ability but also by his way of participation.

Analysis: Comparison of two cases

In this section, I will summarize the differences between Karl and Max in the ways of participation in the community of practice. The table below sums up the activities of M.S. students in the lab. The activities are composed of academic and non-academic activities, and "formal activities" (organized by the university and the lab), and "informal activities" (led by students themselves.) Thus, the activities are classified into four categories as shown in the table.

Activities	Academic	Non-academic
Formal (Institution-Initiated)	Classes Periodic lab meetings Conferences	Seasonal lab events Spring welcome party Summer retreat Fall hike/BBQ Year-end lab clean-up Year-end party Farewell party
Informal (Student-Initiated)	Research-related Read journals Make samples Measure samples Use computers Share artifacts Classes Attend the same classes Sit together Collaborate on homework Study together before exams Student-run study sessions Organize **Participate**	Lunch/dinner gatherings Chat in the lab Smoke together Watch TV Parties without faculty Organize Participate

Table 1. Activities of the first year master's students

Among all the activities listed above, Karl participated only in academic activities: research-related activity (academic informal) and periodic lab meetings and conferences (academic formal). On the other hand, Max participated in all activities in the table. Max, who was a student in the master course, became incidentally involved in various activities in the institutional setting. For example, it was necessary for Max to ask his peer master course students about class homework. This was necessary because he had to attend classes as a formal academic activity. Max and his peers had opportunities to help each other finish homework, an informal academic activity. Furthermore, Max was naturally allocated the role of co-organizer for the lab events such as the picnic and the summer trip, because of his position as a new master course student in the lab. (In this lab, traditionally, new master course students would be allocated the role of organizing lab events.)

In this way, Max obtained many opportunities to interact with his Japanese peers and, as a result, became trusted by other lab members as well. This is how he could know the locations of various machines and equipment and know what kind of research could be conducted in the lab. Max could get to know the details of how to deal with machines and equipment far beyond the information provided in machine manuals. These are vital resources for students to conduct experiments, and thus to practice science. In short, he could naturally access to machines and equipment in the lab. This case shows the complementary nature of informal and formal activities.

Unlike Max, Karl was an exchange student, and not an official student at this Japanese university. As such, he did not have to attend classes (formal academic activity), nor did he have to participate in preparation for lab events (informal non-academic activity), which was perceived as an extra chore by all the lab members. Consequently, Karl and Japanese students did not have any chances to get to know each other, and Karl failed to win the trust that was necessary for access to machines. Although Karl and Max started in similar positions in the community of practice, their ways of participation and their trajectories became quite different in the end.

These kinds of cases illustrate how formal and informal activities, or canonical and noncanonical communities (Brown & Duguid, 1991) are so deeply related as to be inseparable. In other words, informal activity and noncanonical community cannot be organized independently of their formal and canonical counterparts. Informal activities, or noncanonical communities, are constituted dependent on the ways that formal activity or canonical community are organized.

Related to these issues, Wenger (1990) provided that following analysis for why newcomers to the insurance company Alinsu felt great difficulty: Even though they formed a network among newcomers in training class, they were placed in different divisions. Thus they could not maintain this network after they moved to the floor. Moreover, on the floor, old-timer claims processors were constantly feeling pressured; in addition, they did not recognize the need to help newcomers, so newcomers were isolated and many left the job in a matter of few weeks. This case shows that the training class was there for different purpose (training) but it also created the opportunity for newcomers to form an informal network. The case of Max is the opposite case of this claims processors' case. In S lab, the informal network developed in classes was continuously maintained and helped Max's access to machines and other resources on the floor (i.e. the experimental rooms.)

Regarding informal occasions, Wenger (1990) argues that for the claim processors in an insurance company, the daily work and participation in informal rituals (such as celebration of someone's birthday or exchange of Christmas presents) are complementary and form the texture of the practice as a whole. Not only is participation in informal activities complementary

to formal activities, but participation in informal activities also supports the formal activities (i.e., facilitates access to machines to conduct research).

In short, the case above illustrates that participation in a community of practice, such as conducting experiments in a graduate science lab, is not a merely participation in a single activity. Participation is accomplished by interacting with community members in various interwoven activities that may appear on the surface to be more or less related to the central activity.

Conclusion

In this paper, first of all, I illustrated that access to lab practices is socially organized, by analyzing how two IGSs were able or unable to access machines. For example, I showed that access to machine was coordinated and controlled by the gatekeeper who would maintain and arrange the schedule of the machine use. In this sense, machines in lab can be regarded as a social system. This matter of access became visible by focusing on contrasting cases of IGSs.

Secondly, I showed how their trajectories of participation were different and how these differences made facilitated or restricted their access to scientific resources.

The trajectory of participation in communities of practice is organized and accomplished through participation in multi-layered activities and situations. In other words, I illustrated communities of practice as composed of various interwoven activities such as formal/informal and academic/non-academic activities. Accordingly, a trajectory of participation in community of practice should be described not as linear process such as peripheral to full, but as participation in multi-layered activities and occasions that mutually constitute each other as well.

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