On the Transmission of Tacit Skills in Science: Notes on and Observations of Japanese Doctoral Science Research Training Laboratories

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The first author (M) grew up in a community adjacent to the University of the Philippines at Los Baños (home to the International Rice Research Institute that pioneered the Green Revolution in Asia) where attributions of deference, prestige, high status, and success were strongly tied to one's academic degrees. Such attributions were also tied to the places from which these degrees [e.g. Australia, Germany, Japan, United Kingdom, and United States (U.S.)] were obtained. There, it was not unusual to hear about neighbors going abroad, not for leisure or vacation though, but for doctoral science training. Celebrated and popular destinations were—and still are—universities in Australia, Japan, and the U.S.

One training destination in particular—Japan—fascinated M. That fascination was mainly a consequence of M's father's admiration for anything Japanese, which rubbed off on to M through their many dinnertime conversations. Several years later, that same fascination was further reinforced when M was working on his dissertation entitled "Dynamics of Globalization in Philippine Scientific Communities," through which he engaged 315 scientists from Australia, Japan, U.S., and locally-trained Filipinos in qualitative (in 2004) and quantitative (in 2005) interviews about their doctoral training experiences, research activities, collaborative engagements, and professional careers.

In that dissertation and the derivative publications from it, M noticed that even after including multivariate statistical controls, Japan-trained Filipino scientists were significantly more collaborative and productive in terms of peer-reviewed journal publications than colleagues trained elsewhere (Ynalvez & Shrum, 2009, 2011). This intriguing finding inspired us to embark on a project—funded by the National Science Foundation—that allowed our research team to examine Japanese doctoral science mentoring and training practices. This time, our approach was not through interviews with students who studied in Japan and who had returned to their home country after graduation. Our newer approach was through face-to-face interviews and observations at the actual sites of action and interaction (i.e., Japanese university scientific labs where doctoral mentoring and scientific knowledge production take place).

At the closing session of the 1st American Association for the Advancement of Science (AAAS) - National Science Foundation (NSF), Science of Science and Innovation Policy workshop in Washington, D.C. in March 2009, Stephen D. Nelson, Associate Director, Science and Policy Programs, AAAS and Irwin Feller, Senior Visiting Scientist, Science and Policy Programs, AAAS spoke about tacit skills in science. In separate remarks, they reiterated the promise and criticality of understanding the role of tacit skills in the scientific knowledge production and innovation process (Collins, 2010; Lee, Miozzoa, & Laredo, 2010). Tacit skills are skills acquired through close interaction, hands-on work, and exchanges between collocated scientists (Collins, 2010).

These skills have been shown to play a significant role in creativity, innovation, and productivity in experimental (Collins, 2001) and mathematical (Kaiser, Ito, & Hall, 2004) sciences, laser-development (Collins, 2010), and even nuclear weapons development (Mackenzie & Spinardi, 1995). However, the nature and transmission of tacit skills has been a generally understudied and taken for granted topical area (Insch, McIntyre, & Dawley, 2008), particularly in the context of training future scientists (Leahey, 2006). In concurrence with Campbell (2003) and with Delamont and Atkinson (2001), we contend that the transfer of tacit skills in science constitutes a crucial area of research in doctoral science mentoring and training.

Hence, in this research brief, we share first-hand micro-level comments and observations of mentoring practices and laboratory "social environment" in two elite and highly productive Japanese doctoral science training institutions in Tokyo. With the hope of learning from Japanese mentoring practices, and generating research hypotheses that would help improve international doctoral science training practices, we link our observations to how these practices might either facilitate or preclude the transfer of tacit skills in science (Collins, 2010).

Study Locations and Methods

The visits to and the observations of laboratories reported and discussed in this research brief were conducted by research team members in two doctoral science research-training institutions in Tokyo, Japan: Tokyo-1 and Tokyo-2.[1] These visits and observations were conducted in June 2010 and in June 2013. Tokyo-1 and Tokyo-2 are top academic research institutions that aggressively contribute to the international knowledge base in the life and the chemical sciences. These universities are home to Nobel Prize winners and many world-class scientists in the natural and the physical sciences.

Although our interviews in 2010 and in 2013 were conducted in both Tokyo-1 and Tokyo-2, the weeklong lab observations in June 2010 were conducted in a selected life science lab in Tokyo-1. The weeklong lab observations in June 2013 were conducted in a selected chemical science lab in Tokyo-2. The rather short duration of our lab observations was the result of many conspiring and limiting factors. These factors were the difficulty in obtaining access, consent and permission, and the high-volume of lab

Figure 1: A doctoral science research training lab in Japan (June 2010).

activities that could potentially be disrupted by our social research activities.

As a peek into a typical day of our lab observations, M would arrive at the lab at about 9:00 AM and would stay there the whole day. There were days that M would leave the lab at about midnight or a little past midnight—yes, the labs were still steaming busily even at those times. As much as possible, because of the busy schedule and the high-volume of activities in the lab, M intentionally and mindfully minimized interactions with lab members. However, M made it a point to chat with them either during break times, lunch, or dinner to gain deeper understanding of lab dynamics and undertakings.

While it was impossible to eliminate the threat to validity due to reactivity (the Hawthorne effect and demand characteristic effect), M earnestly tried to shorten and hasten the time that his presence was "normalized" in the lab. M did this by minimizing unnecessary movement in the lab, minimizing interaction with lab members except during break times, and intentionally dressed in a manner that made M appear like one of the students. In conducting these observations, our objective was to understand how scientific skills were transferred from mentors to mentees in doctoral science training.

Observations and Comments

Observation 1: A mentor-mentee relationship that was highly interactive coupled with a high-degree of co-presence. The typical workday in the labs started at about 9:30 AM (the median for professors was 9:00 AM, while that for students was 10:00 AM). It was not unusual for professors and students to have lunch and dinner in the lab, and to work until 10:30 PM. However, we also observed that some professors and students worked until 2:00 AM. Excluding administrative and teaching responsibilities, the average professor spent 42.6 hours a week doing research, while the average doctoral student spent 64.0 hours per week. In terms of research guidance, each student often had an adviser and a mentor, who were often not the same individual. The former was usually a senior (full) professor, who heads the lab. The latter was typically one of the junior professors (e.g., assistant professor, lecturer, or associate professor).

Relationship between mentor-mentee involved close, informal, frequent, and friendly interactions coupled with a high-degree of co-presence. The workstations of junior professors were located within the lab where students also had their study areas. It was our first time to observe an arrangement where a faculty's desk was literally side-by-side their students' desks. We felt that this arrangement created an environment conducive to intensive and meaningful face-to-face interaction, a crucial factor in the acquisition and transmission of what Collins (2010) referred to as relational tacit skills, and in learning the common expressions, gestures, language, and subjective meanings that go with acquisition of collective tacit knowledge.

In earlier interviews—2004 and 2006—with Japan-trained Filipino scientists, these close and frequent interactions between mentors and mentees were construed as pivotal in the emergence of a strong sense of community and commitment among lab members. In those same interviews, such opportunities for exchange and interaction were frequently alluded to as one of the reasons explaining the high levels of productivity in Japanese labs. Intense (detailed, frequent, long-duration) mentor-mentee interaction was clearly one practice that differentiated Japanese mentoring style from that of the U.S. model. This practice also highlighted how the social dynamics within the research lab might influence scientific practice and output. Some (e.g. Johannessen, Olaisen, & Olsen, 2001; Hara, 2009) argued that information and communication technologies (ICTs) are not particularly appropriate for sharing tacit skills. With a predominantly face-to-face and intense interaction, we are curious to ask: How have new ICTs impacted the dynamics of mentoring, and more importantly the honing and the transferring of tacit skills?

Observation 2: Senior-junior mentoring for both doctoral students and junior professors. Even with the close, friendly, and frequent interactions between junior professors and their students, the configuration of relationships within the Japanese research lab is distinctly hierarchical, in which lab members were cognizant, conscious of, and sensitive to status and role differences. While students were mentored directly by and interacted closely with junior professors, we also observed a practice in which these same junior professors were also mentored and supervised by the senior (full) professor who headed the lab—this was the person who everyone else (including ourselves) deferentially called sensei. In contrast, junior professors were "alternately" addressed by their mentees as either san and/or sensei (e.g. Tanaka-san or Tanaka-sensei).[2] Some might argue that this relationship suggested a form of hierarchical structure that was constraining and limiting creativity, freedom, and independence of junior scientists in pursuing their own research. Our take is that within reasonable bounds, such practice also built confidence and provided professional direction for junior professors, because it served as a form of professional "scaffolding" (Pea, 2004). For example, the practice of senior faculty socializing and mentoring junior faculty to the discipline is a strategy encouraged in U.S. universities. The intent is to jump-start the professional careers and focus the research agenda of assistant professors on tenure-track.

The main difference though (between Japanese and U.S. training), was junior U.S. professors were able and expected to immediately pursue their own independent research upon being on tenure-track. In the case of the Japanese labs we visited, our respondents reported that granting independence to junior professors was mainly at the discretion of the sensei. Indeed, the challenges and expectations for junior professors in the labs we visited were how to be "creative within a strictly hierarchical system."

This system of mentoring could make the entire team (senior professor, junior professors, post-doctoral fellows, and doctoral students) either all productive or unproductive. We first-handedly heard some anecdotes, usually from senior professors (sensei), that they had to separate themselves from their unproductive mentors when they were young. This "all-or-nothing" mentoring system carries a certain risk of putting everyone on a single boat. With these challenges, we forward the question: how do the ascribed (age, gender) and the achieved (education, occupation) bases of hierarchy influence mentor-mentee interaction, and the acquisition and transmission of tacit skills?

Observation 3: A predominantly insular lab social environment. Kiyoshi Kurokawa described Japanese academic institutions as still largely insular and inward looking, a description which quickly became crystal clear to us through our conversations with senior and junior professors and doctoral students (Kurokawa, 2008; Normile, 2007). Compared to those in the U.S., Japanese research labs were characterized by low levels of diversity in terms of the international mix of faculty, post-doctoral fellows, and doctoral students. Some contend that Japan must open its doors to international talents to further enhance innovation and boost creativity (Normile, 2007). It was also evident that while other non-English speaking countries are working toward using English as one of the modes of instruction, Japanese doctoral science training is conducted in Japanese. It requires foreign graduate students to take Japanese language courses. From another standpoint though, the insularity of the Japanese training system can be construed as a means to developing homegrown talents. Indeed, according to one of our respondents, Japan needs talents who are capable of addressing and understanding the sensitivity, uniqueness, and nuances of local concerns and problems.

The high degree of insularity in Japanese research labs, while seemingly undermining diversity in ideas and perspectives, could also mean the efficient transmission of tacit skills from experienced mentors (professors) to novice mentees (doctoral students). In a way, we interpret this as an expression of what Collins (2010) referred to as collective tacit skills. As one junior professor puts it: "While Japan might not be using English in instructing, mentoring, and training its future scientists, or in doing science, Japan is in a unique position wherein our everyday language is also the language of our sciences…now not many countries do that and I can see both the strengths and the weaknesses to that practice, but I think it is an interesting situation to explore."

This respondent was highlighting the inherent advantage in communicating and transmitting knowledge, and attributing meaning among experts themselves, between experts and non-experts, and between mentors and mentees afforded by having a common language base. In fact, a Taiwanese professor who was trained in a Japanese university criticized the trend to educate young scientists in English—a non-native language for his students—in Taiwan. He commented that the scientific concepts are already complex, and students have to learn those concepts in a foreign language. He strongly supported the way that Japanese universities use Japanese to educate future generations of scientists.

Thinking of M's own country of origin (the Philippines) where the medium of instruction in that country's schools and scientific institutions is the language (English) of its former colonial-master (the U.S.), we again asked ourselves: Would having English as the mode of instruction in Japanese scientific institutions afford them higher levels of creativity, innovation, and productivity? Will it make them competitive in global science? These are valid questions because few productive scientists in Japan write anything in Japanese anymore. Moreover, English writing skills are an additional requirement in the professional socialization of graduate students and junior faculty members. In addition, we also ask the question: Does it really matter—in terms of creativity, innovation, productivity, and visibility—what language a country's educational and scientific institutions adopt and use?

Observation 4: A scientific lab environment that is still predominantly male. Although there were many female undergraduate and graduate students, their numbers steadily decreased as one went up the professional scientific hierarchy—from postdoctoral fellows, assistant professors, lecturers, associate professors, and finally, to full professors. While there are serious efforts to break the barriers of gender (or gender inequality) in science in Japan, it is still a major challenge, especially if female Japanese scientists are still expected to handle—upon getting married—child care, housekeeping, and caring for aging parents and parents-in-law by themselves. Based on our conversations, the predicament of married female Japanese scientists was very exacting, given that all these domestic expectations were added to the professional demands of being a scientist. Hence, the typical response of female junior scientists was to either remain single/childless or give up their professional careers upon marriage/becoming a mother.

However, it appears that change is imminent, judging from the excitement of a female junior scientist, who shared with us that she admired her male sensei for being active in an on-campus movement espousing a gender-equal work environment and opportunity structure. This is indeed encouraging news when a respected and prominent male professor takes on an active role in the pursuit of gender equality in science. Asked about her plans for the future, this respondent said that "a postdoctoral fellowship at a prestigious European or U.S. research institution or university is an option…after that…I don't know." A statement like this not only reflected a female scientist's aspiration to try professional career opportunities abroad, but also clearly articulated the uncertainty in career trajectory that a young doctoral-trained female Japanese scientist faced due to a lack of female role models.

However, amidst the uncertainty of and gender inequality in career opportunities in science, the women we interviewed were described by their male professors as extremely competent and highly proficient researchers. As a junior professor proudly stated, "Hiromi, one of the female doctoral students in this lab, is very good in doing photography with the microscope… she is far better than me or any other students in a predominantly male lab…the photos she generates are of the quality that is for a Nature or Science article….Really I don't know how she does it."[3] From this account, the tacit skills, involved in generating high-quality microscope photography, were embodied in Hiromi. Her mentor's statements about not being able to fully comprehend "how Hiromi does it" might have resulted from Hiromi's innately unique qualities (somatic tacit skills according to Collins, 2010); or from the fact that the transfer of such skills to others in the lab may have proven challenging and difficult, given the set of mores and norms that governed exchanges and interactions between males and females. It could also be a form of tacit skills (collective tacit skills) that could not be fully articulated and transmitted. Maybe because this required that the collectivity transcend barriers of social categories (young versus old, male versus female) that emanate from the larger socio-cultural context (Kohler, 2010). Might a freer, egalitarian, and equal-standing between male and female, or young and old scientists make the transmission of information and tacit skills less difficult?

Observation 5: Laboratory-research teams that were predominantly "academically inbred." Our conversations with doctoral students made us realize that it was not unusual for them to train in one lab and/or university beginning with their undergraduate up until their post-doctoral training. In the labs we visited, junior professors received their undergraduate and graduate training in the lab where they were presently working. Over freshly brewed Starbucks™

coffee, one junior professor stated: "You know what, it is still very common in Japan to find labs consisting of scientists who are "100% made in Todai" (The University of Tokyo) or "100% made in Kyodai" (Kyoto University)…Once you start your undergraduate in a particular university the tendency is to stay there until your post-doctoral years…Maybe even until your early professorial years." Asked why this was the case, our respondent said that it had something to do with a "sense of loyalty" to the sensei and to the people, who were pivotal in their becoming scientists.

Although there are serious attempts to encourage "crossovers," to foster local diversity, these are still a rarity. This was an interesting phenomenon. Reflecting on it, we asked ourselves these questions: Might it be that academic inbreeding occurs more frequently among elite labs and universities, wherein such places of science would rather hire their own graduates than those from less prestigious places. How does a strong culture of academic inbreeding, intersected with a high degree of insularity, influence the flow and transfer of tacit skills in science? How might that flow take place within the microenvironment of the research lab, and across the macro-environment that is the larger national scientific research system?

CONCLUSION

Our intention in this research brief is to spur research efforts in the transfer of tacit skills in doctoral science training by way of forwarding empirically grounded insights, hypotheses, and questions from our lab visits. The observations and comments we shared are not meant to generalize to the overall doctoral science training system of Japan. These observations are not generalizable—this was not our intention. Rather, we intended to help trigger a series of reflective thinking at a time when national scientific cultures are undergoing rapid changes because of the rapid globalization of science. The Japanese research labs, the context of our observational study, are some of the most productive in the world. Yet, much of its mentoring and training practices stand in stark contrast to those of the research training systems in the Western developed countries.

In general, Japan's present stance is seen as hardly "in sync and aligned" with globalization, and yet Japanese scholars are major global players in the production of scientific knowledge and innovative technologies. With our visit to their labs, we intended to learn from their doctoral mentoring practices. Although these visits generated many important insights, they also prompted many new questions that have the potential to inform future research directions on how socio-cultural context shapes scientific practice, and ultimately science (Collins, 2010; Kohler, 2010).

In regards to M's fascination with Japanese doctoral science training system, our lab visits inspired us—all four authors of this research brief—to carry on with a research agenda in which we attempt to further detail and elucidate the "socio-cultural situatedness of science" in the context on the non-West (Kohler, 2010).

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ENDNOTES

[1] To maintain the privacy, we do not use the real names of these institutions.

[2] To protect our informant's privacy, Tanaka-san and/or Tanaka-sensei are fictitious names.

[3] To protect our informant's privacy, Hiromi is a fictitious name for a real female Japanese doctoral student.

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