A Model for International Summer Research Experiences for STEM Students

Mika Munakata*, Department of Mathematics, Montclair State University

Su San Lim, Department of Mathematics, Montclair State University

Carlos A. Molina, Department of Biology, Montclair State University

*corresponding author. munakatam@montclair.edu

Abstract

In this article, we report on a National Science Foundation-funded immersive international summer research program for biology students. Six students, representing Cohort 1 of a three-year program, spent nine weeks at one of three institutes in Japan, working on related molecular, cellular, and developmental research projects under the mentorship of a Japanese researcher. We describe the recruitment process, pre-departure activities, orientation week, research projects, and mentorship structure. Data were collected to determine the impact of the program on students' views about science and to seek feedback about the structure of the program. The pre-, mid- and post-program interviews with the students as well as their weekly written reflections revealed that the program challenged their perspectives about science, broadened their understanding of what it means to engage in science research, and contributed to their growing confidence as budding scientists. The students mentioned that certain elements of the program, including the orientation week, weekly meetings, and individualized and hands-on mentorship they received, contributed to their rich experience in Japan. Suggestions are provided for adapting this model to develop other international opportunities for STEM students.

Keywords: International, Student Research, Biology

Introduction

According to the Institute of International Education (2022), about 16% of US undergraduate students study abroad. The benefits of these experiences include improvements to students' intercultural awareness and academic performance (Ingraham & Peterson, 2004) as well as adaptability to new situations (Zimmermann & Neyer, 2013). Most study abroad programs, however, are not discipline-specific and few are focused on science, technology, engineering, and mathematics (STEM). In this paper, we report on a summer research experience for US biology students to work in laboratories in Japan.

Given the heavy course and laboratory requirements for most STEM majors, it is important to consider alternative models to traditional semester-long study abroad programs. Dwyer (2004) found that summer programs that are deliberately planned and are at least six weeks have the same benefits as semester programs. According to the IIE (2022), only about 5% of study abroad opportunities, however, involve students doing research. We drew from the literature on the benefits of undergraduate research experiences (Mraz-Craig et al., 2018; Russell et al., 2007) and designed an immersive research experience in an international setting that would allow participants to work and become part of the community.

Description of the Program

Our program, funded by the National Science Foundation's International Research Experience for Students (Award #1952513), involves six students in each of three years spending nine summer weeks in Japan. In this paper, we report on the activities of Cohort 1. Students are provided with round-trip airfare, housing, and a $5000 stipend for their participation in the program.

Recruitment and Selection

The program was coordinated by faculty at a mid-sized public university in Northeastern

US, and open to students from all US institutions. We sought to include students underrepresented in STEM fields. As such, we recruited primarily from historically black colleges and universities (HBCUs), Hispanic serving institutions (HSIs), and women's colleges. We sent emails to department chairs and offices of international engagement and posted notices on websites of organizations including *Pathways to Science*. We held three webinars for prospective students to provide an overview of the program and guidance on the application process.

Applicants submitted an essay, two letters of recommendation and a transcript. In all, 38 students applied: 15 were selected for interviews and six participants were selected based on their plans to pursue a career in research, expectations for the program, and potential to contribute to their laboratories. The students were a diverse group, including a student from Puerto Rico, a student from an indigenous culture, a non-traditional (returning) degree student, and a first-generation college attendee. Remarkably, all six students came from bicultural backgrounds, with five students fluent in at least two languages.

The Program

The program began with pre-departure activities. We met online for 1.5 hours biweekly during the spring semester. All students were assigned scientific articles to read and were sent a book on conversational Japanese. In the first week, we unveiled the matching of the students with a Japanese research mentor, based on their scientific experience and interests.

For subsequent meetings, each student prepared a presentation on the research activities of their assigned laboratory, as well as an overview of their host city. They also led a discussion on an article published by their mentor. Other activities during the pre-departure meetings included language instruction, planning, and discussions about cultural considerations.

Once in Japan, orientation week was led by the two project directors and took place at Institute A. Each Japanese mentor gave a seminar related to the work the students would do. The topic of their seminars became the basis for further discussions. The week was also spent acclimating the students to life in Japan. They practiced buying food at the store, buying train tickets, and ordering at restaurants. A one-day excursion to a large city in central Japan introduced them to the train system and navigating big cities.

For the rest of the program, students worked in pairs at one of three institutes in Japan: Institute A, B, or C. At Institute B and C, each pair was mentored by a single researcher; at Institute A, each student was mentored by a single researcher. All four mentors are world-renowned researchers in their respective fields.

Students stayed in single-unit housing and had access to a kitchen. This was an important feature of the housing arrangement because students had to set up their apartments and shop for groceries–activities that required them to interact with the local community.

The Science

The students were assigned research projects by their mentors. All of the projects were related by a common theme: genetic expression in medaka and zebrafish. The objective at one of the laboratories at Institute A was to explore the expression of certain RNAs in the neuronal glial cells of zebrafish embryos. The student used a novel technique, HCR RNA-FISH, on whole zebrafish embryos to visualize the expression of various RNAs using confocal fluorescence microscopy. The other student at Institute A examined the length of telomerase in inbred zebrafish. This laboratory had made the observation that inbred zebrafish have a shorter life span than the non-inbred counterpart fish and hypothesized that inbred zebrafish have shorter telomeres.

At Institute C, one student worked on generating mutant medaka fish using CRISPR-Cas9 to delete genes suspected to be involved in seasonal and circadian behavior. The other student tested novel natural products in human cell cultures. Using a quantitative PCR technique, he studied how these compounds affected the expression of genes involved in circadian rhythms. Additionally, both students helped collect wild puffer fish for the dissection of organs to determine gene expression related to seasonal mating.

The two students at Institute B generated a DNA construct to be used in transgenic medaka fish. This "reporter" DNA construct can be utilized to visualize the expression of genes related to circadian rhythms in the organs of live fish using novel fluorescence microscopy techniques. Ultimately this transgenic fish could be used to determine the effect of compounds on the expression of genes related to circadian rhythms and jet lag disorder. They also tested whether a novel protein, Cas12a, could be used as an alternative to Cas9 for the generation of mutant medaka fish. They successfully generated proof of concept data for the deletion of specific genes using Cas12a.

Methods

These research projects served as the backdrop for the students' international experiences. Our hope was to learn from the participants' experiences to further develop our program and also to inform others developing similar programs. We collected data to answer two research questions:

1.) What features of the program did the students indicate as contributing to their experience?
2.) What were students' reflections about their scientific and cultural experiences?

Data were collected pre-, mid- and post-program through interviews and surveys. The

surveys were modified from Siaya and Hayward (2003), Sadrozinski (2008), and the Global Perspective Inventory (Braskamp et al., 2009). Due to the small sample size, we did not use the surveys for quantitative analysis, but they helped us individualize the semi-structured interviews. The interviews were conducted by Author 2 through Zoom and took between 30 and 45 minutes. The pre-interview focused on past international experiences and expectations for the program, while the mid- and post- program interviews sought to determine the participants' reactions to the program. The post-program interview protocol is presented in Appendix A.

Data were also collected weekly through written reflections, timesheets, and group meetings. All interviews and weekly meetings were transcribed. We highlighted all relevant passages in these transcripts, as well as in the weekly logs and separated them by distinct comments. We then identified themes related to elements of the program participants found useful (or not) and their reflections on the impact of the program on their understandings about science, self, and culture. We assigned a pseudonym to each participant.

Results

Format of the Program United Students

Almost all of the students mentioned the importance of the pre-departure sessions on their experiences: that they helped familiarize them with the language and science. They also expressed their appreciation for the orientation week in Japan. Not only did it "acclimate us to being in Japan" (David), but it also created bonds among the students that were sustained over the nine weeks. As Franky put it, "it strengthened and basically built a bond between all the participants of the programs…they united us in a way that was really nice."

Another attribute of the program that brought students together was the weekly online meetings and other group meetings while in Japan. Although the participants lived in different

cities, they often traveled together on weekends. Abigale had this to say about the online meetings:

> Having the group helped people not only discussing science, but also with encouraging each other to actually get the full experience of being on the other side of the planet. We were united by the program but still somewhat independent during the week, people would have little experiences, and then share them with a group…and you can't do that unless you're in a group, especially when (we) are in very different labs.

Mentorship Accommodated Students' Experience Levels

The intensive laboratory experience, supervised by the Japanese researchers, allowed for students to grow in their capacity to do science and enhanced their confidence. The students represented various experience levels. Emery, a PhD student, was appreciative of the trust given to him by his mentor:

> And the amount of trust that was given and independence and doing my own experiments…managing myself and my own time and pacing myself in the work environment. I think that (was) another really good thing I learned as a scientist. I have more of a passion for research because of this experience, because I was doing things by myself so much, and it really made me reflect upon just the subject as a whole.

Others, who were undergraduate students and therefore less experienced in the laboratory, received more hands-on mentorship, especially at Institute B. Abigale, whose previous laboratory experiences were online due to COVID 19, felt "lucky…I'm learning for the first time and (her mentor) has been very patient with me, which I'm grateful for. And I'm really amazed he never gets frustrated or anything". The same mentor was appreciated by Crystal, who said that "I think we are where we are now, because (her mentor) is a very hands-on mentor. I

think it's no understatement to say that I think he really did change my life by allowing me this opportunity".

Immersive Nature Brought Students Closer to the Community

Another theme was the importance of students' interactions outside the laboratory. They played soccer, took language classes, went to dinner, and explored the city with lab mates. Through these interactions, the students formed new friendships and learned more about both the Japanese and their own culture. Even in sports, participants noticed cultural differences: "The dynamic in a sport activity was very different and also helped me understand more of how much respect for the older generation the population has" (Franky). Interactions with lab mates outside of work allowed students to "talk about the different things we grew up with, particularly movies and TV shows!" (Emery). David commented that "I always love hearing their impressions of the US and then sharing my own perspectives – and vice versa with my impressions of Japan."

The duration and immersive nature of the program was also appreciated by Crystal, who compared this experience to her previous visit to Japan:

> But now that I am an insider and no longer an outsider - I work and live here - the feeling of being distinct has lessened…these are countries and continents that are extremely stereotyped and polarized in the Western world. And unless you actually travel there and see it for yourself, I think you can watch TV, I think you can watch magazines. But I do think it's an entirely different experience getting to go there in person.

Changes to Views About Science

With regard to the impact of the program, the international experience afforded students a chance to reexamine their views about science. Bobby noted differences in how researchers interacted:

> In the United States, science definitely feels a bit more individualistic…And I think everyone wants credit, because everyone wants the rewards from that. And I definitely don't think that that's how things are in Japan. And so I think that's just a big relief…scientists are truly just there for science, rather than they're trying to get a lot of attention. Because I think that's really where I see myself in the future as well.

It is notable that Bobby not only noticed this difference in perspective, but also vowed to incorporate it into his work as a researcher. In a similar vein, Franky became aware of US-centric views of science:

> Because their (Japan's) science is really nice, their science is like, good quality. So, that you're not going to learn in the US, because in the US, they're always like, 'Oh, this is the best science and it is good science', but (it) excludes other countries' good quality science as well.

Participating in science outside the US made several students realize the global nature of science: "I didn't really understand that there's these big, collaborative efforts where people come together" (Abigale). Though there was a substantial language barrier, students also came to see that "science in and of itself is almost a language" (Bobby).

Self Efficacy Related to Science and International Collaborations

The two-month experience helped students become more comfortable with their science skills as well as with navigating a new culture. Several students noted their increased confidence as researchers. For example, Crystal recalled that:

> I started to kind of take more of a lead role in some of the projects where I started to understand what we were doing, and I knew where everything was. And so I could start to do these things. And then I could, almost like a regular PI, go back to (her mentor) and

be like, this is what I did, what should we do further.

With regard to their comfort living in a different country, participants expressed that the program "taught me not to be so intimidated by other cultures" and that "going to other countries doesn't seem as scary" (Emery).

Students noted that their "career options have opened up" (Abigale) as a result of the program. One student became motivated to pursue a PhD, while others considered applying for PhD or post-doc programs internationally. As David put it: "The opportunity to insert myself into a new atmosphere with an entirely different culture and language has been exceptionally refreshing and I can see myself seeking that out again in the future for a more long-term period of study". Abigale came to realize that she wanted to continue working on international collaborations: "I want that kind of a career that's not limited to one space where I can do research in another place, and then potentially connect that back to labs in the US…I am really interested in that. I had no idea that that kind of stuff happened".

Four of the students expressed interest in developing similar programs for their future students. Having participated in this program, Crystal gained some confidence to do so: "I also think that now I'm a little bit more qualified for a job like this. If I can show that I've got experience. I've been in different cultures, and I've been in these different collaborations, and I think I could do a good job with it." In this way, the program has the potential to be sustained through the participants' future international initiatives.

Conclusion

The summer experience served as an alternative model to typical semester-long study abroad programs. The outcomes of the program on participants' scientific knowledge, research skills, and cultural awareness attest to the importance of providing STEM students with

opportunities for international engagement. Its impact on students' growth indicates that even a two-month summer program has the potential to change students' outlook on science and their engagement with science in a profound way.

The reflections from students revealed several lessons for subsequent cohorts and other programs. Meeting with the group biweekly for almost four months before the program provided the students with the relevant scientific background and exposure to the language and culture of Japan. They also formed an initial bond so that they were familiar with one another when they met for the first time in Japan. Even with this preparation, however, the language preparation could have been more intensive. The recommendation from the students was that future cohorts be required to take Japanese language courses at their home institutions before the summer experience. In terms of the structure of the program, all participants appreciated the one-week orientation in Japan and the weekly online meetings thereafter. The pairing of the students provided a balance between independence and support. Because the students were not a part of a larger group, each student was forced to navigate day-to-day activities independently, but had a partner to support them as necessary.

This model of international engagement can be adapted for other disciplines or partnerships with other countries. Although ours was a funded program, the model can be transformed to a research course experience where students earn credit to work with their US mentors' international collaborators. It can also be used as a model for a more formalized research exchange program. Unfortunately, due to the stipulations set by the National Science Foundation, our program could not be a true exchange program: we were unable to fund Japanese researchers or students coming to our campus in the US. Programs that support international partners' visits to US institutions thus would be an improvement over our model.

Regardless of the form it takes on, providing opportunities for STEM students to work in laboratories abroad is one step towards supporting their participation in science at the global level.

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Ethics Statement

This study met the ethics requirements for human subjects. All participants consented to being in the study and all measures were taken to anonymize the data. The institutional review board of Montclair State University approved the study (IRB approval number 21-22-2476).

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Appendix A.
Post-program interview completed in the last week or upon return to the US

1. In the mid program interview, you said… Has this changed?
2. What parts of the program met your expectations? What parts surprised you?
3. How did your experience with the program and international collaboration change from Day 1 to the end? In what ways did you adjust your communication or collaboration strategies?
4. How did you grow as a scientist over the course of the nine weeks?
5. What new insights do you have about:
    a. the nature of science and about doing science?
    b. international collaborations?
    c. yourself?
    d. your own culture?
    e. other cultures?
6. What will you remember 20 years from now?
7. Can you describe a moment when you felt challenged?
    a. What made it challenging?
    b. Do you think you met or overcame the challenge?
    c. What helped you through it.
8. Can you describe an experience that caused you to question the way you normally act or think?
9. What was the biggest surprise or unexpected feature of your experience?
10. What were some challenges you faced? How were you able to overcome them?
11. Who supported you during your time in Japan? How?
12. How will you attempt to sustain the professional relationships you've built?
13. Is there any part of your research experience you plan on continuing once you get home?
14. What are your plans for the next year?
15. Is there anything you'd like to add?