US-Japan NSF IRES Program for Developing Portable Point-of-Care Testing Devices: Preparation and Experiences of Year 1

Sangjin Ryu[1], Jessica Deters[1], Jonathan Janecek[1], Christian Sunderland[2], Laurel S. Wagner[1], & Rachael Wagner[1]

[1]University of Nebraska-Lincoln (UNL) / [2]Nebraska Wesleyan University

Abstract

The International Research Experiences for Students (IRES) program of the National Science Foundation (NSF) focuses on developing a diverse, globally engaged STEM workforce through international research experiences. This NSF IRES project aims to develop a portable point-of-care testing (POCT) device for efficient detection of infectious pathogens by integrating microfluidic devices and a filter-free wavelength Complementary Metal-Oxide-Semiconductor (CMOS) optical sensor in a portable platform. The program supports an 8-week-long summer research experience at Toyohashi University of Technology (TUT) in Japan for a cohort of undergraduate and graduate students. This paper reports on the first year of the program.

Keywords

International research experiences, Microfluidics, CMOS sensor, Research abroad

Introduction

The International Research Experiences for Students (IRES) program of National Science Foundation (NSF), which has been operating since 2006, provides international research experiences for undergraduate and graduate students in science and engineering [1]. The broader IRES program aims to broaden participation in STEM by providing international research experiences to students from groups that have been historically underrepresented in the field [1]. Providing research experiences for students has been shown to increase learning outcomes, research skills, and enrollment in graduate programs [3], [4], [5]. IRES programs vary in structure, with some relying on a single faculty PI in the U.S. to coordinate efforts with a host country (the model of the IRES program in this paper) and others bringing together multiple departments in a network [2]. Faculty-to-faculty model IRES programs have been shown to expand the PI's research areas, publications, and recruitment of graduate students and post-docs, and faculty PIs tend to see greater individual and research benefits under this model [2]. Because IRES programs are unique from one another and from other research experiences, it is important to identify outcomes and lessons both within and across programs in order to improve international research experiences for all stakeholders.

This paper aims to document the first year of an IRES program led by a University of Nebraska-Lincoln (UNL)-based PI and identify areas of strength and improvement for the second year of the program. This IRES program aims to develop a portable point-of-care testing (POCT) device for efficient detection of infectious pathogens by integrating microfluidic devices and a filter-free wavelength Complementary Metal-Oxide-Semiconductor (CMOS) optical sensor in a portable

platform. The program supports an 8-week-long summer research experience at Toyohashi University of Technology (TUT) in Japan for a cohort of undergraduate and graduate students.

Recruitment of the Year 1 cohort

The program was actively promoted through a hybrid-format info session, a program website, flyers, and emails. The website posted detailed information about the project, the IRES site, U.S. and Japan mentors, a recorded video of the info session, and application process. Participating students were recruited from UNL and local universities in Nebraska. Applications were accepted for about two months through the project website. A total of 12 students applied, and four students were selected for the Year 1 cohort.

The cohort consisted of four students of diverse backgrounds. Three of them were undergraduate students in electrical engineering, chemical engineering, and physics, respectively, and one student was a doctoral student in biomedical engineering with a background in mechanical engineering. Among the undergraduate participants, two did not have any prior research experience while one participated in summer research programs previously. The gender ratio of the cohort was 1:1. Two students are Caucasian while the other two have native American and African American heritages, respectively. Three students were from UNL, and one student was from Nebraska Wesleyan University. Two students did not have prior foreign travels. As such, the cohort was formed based on careful consideration of diversity and various levels of research experience.

Preparation of students: Pre-departure training

The IRES scholars were well-prepared for their summer in Japan through a semester-long training program. Regarding Japanese language and culture, the students were provided with a Duolingo membership, and they learned basic Japanese conversation expressions and the practical information and tips on living in Japan from a Japan Outreach Coordinator residing in Omaha. Also, the cohort met students who previously visited Japan to learn about their experiences. For professional development, the cohort was introduced to research integrity and scientific writing. More importantly, the cohort had online meetings with their TUT mentors to know about each other, to learn about research environment of TUT, and to discuss details of research activities at TUT. These meetings helped the students get them familiar with the mentors before their travel to Japan.

Summer program in Japan

At the host site, the cohort went through the general process of research. They received training on the fabrication and testing of CMOS sensors, and the designing, fabrication, and experimentation of microfluidic channel devices. Literature survey and discussion within the cohort helped the IRES scholars gain general knowledge on the status of the art in the POCT technology and specific knowledge on the techniques and sensor that they would use. Through brainstorming and meetings with mentors, the students identified a specific research question for their summer research and overcame technical challenges. At the end of the summer research, the cohort presented their research outcome and summarized their research experiences and progress in a typical format of journal articles. Therefore, the students could gain research experience from initial brainstorming to final scientific writing.

To enrich the cohort's experiences in Japan, various opportunities were prepared to visit local universities or industry. For example, the cohort visited Senshu University, a sister university of UNL, and learned from Ben Norton, a UNL alumnus, about various cultural differences between the U.S. and Japan. The cohort had a conversation table event and lunch with Japanese college students. At Kobe University, the cohort visited various research facilities and participated in engaging events. Also, the cohort visited several companies including Kewpie, Kobe Material Testing Labs, Kawasaki Akashi plant, Yamaha piano factory, and Honda Electronics.

Research and Evaluation

UNL Methodology and Evaluation Research Core Facility (MERC) evaluated the project. These include the pre- and post-program surveys for students, midpoint and endpoint focus groups with students, and interviews with students' mentors. Separately, Deters (Author 2) asked the cohort to participate in additional data collection for research purposes. The cohort was asked to do weekly self-reflection with given prompts, and upon their return, each IRES scholar will be interviewed about their IRES experience. These data will be analyzed in-depth over the next year. Preliminary findings from the student reflections are provided below.

Findings

Students' reflection: what they learned by conducting research in Japan

For their final report, the IRES students, who are co-authors on this paper, were asked to reflect what they learned by conducting research in Japan, and what the biggest cultural differences that they noticed with respect to research.

One student reflected on the working culture, observing that the members in the labs they visited seemed to be friends who spent time together after work:

> In all the labs visited, the culture seemed to be one where everybody was comfortable working with each other, and was very friendly. There was a sense that lab members were mostly a group of friends, spending time with each other outside the lab and throwing lab parties to eat and drink together.

One student noticed how people's different cultural and academic backgrounds impacted how they interacted and thought about problems:

> Working in these labs provided great experience working with people from a wide variety of backgrounds both personally and academically. There were people from all over the world, not just Japan, that played a role in helping with the program. This showed how the cultures that people come from changed the way they work in a lab setting. There were also people from multiple different academic backgrounds that provided good insight into the different ways people are taught to think about problems from different majors.

Another student echoed these sentiments about the diversity of backgrounds across individuals involved in the IRES experience, and reflected on strategies used to overcome communication barriers:

> Working in a research lab internationally amongst team members of several different STEM backgrounds allowed for the creation of a unique project and learning experience. … The success of the program can be greatly attributed to the specializations of our host labs and the dedication of our lab mentors to the project's success, our understanding of new concepts, and desire for our exposure to new cultural experiences in Japan. Through various means of communication, we worked to overcome language barriers and solve problems that lay outside our own degrees.

One student noticed a cultural difference in work expectations – their effort was valued more than their results, so they noticed that they felt less pressure. However, this student noted that they would have found more negative feedback to be helpful to the group's development:

> Throughout the duration of this project, one emphasized cultural difference was the lack of pressure. This difference came from two primary factors: the research group's status as guests and the general Japanese working culture. In Japanese working culture, effort is oftentimes held to a greater value than actual results. As such, since the group consistently worked hard, there was very minimal negative feedback even when things went wrong. While this culture was very good for a first research experience in a new field, it still could feel slightly diminishing at times, as relevant negative feedback very well could have helped the group at times. That said, it is necessary to reiterate that despite that singular flaw, this was an amazing research experience both for experiencing a different culture and what it meant for carrying out the project.

Summary

Overall, the first year of the program was completed successfully without major problems. The effectiveness of the pre-departure training will be evaluated based on analysis of students' responses to MERC's surveys. The IRES scholars could produce a novel prototype to test the detection of a target agent through the integration of a CMOS sensor and microfluidics. They gained unique experience in going through most part of the research procedure in such a short time. Experiences and self-reflection from Year 1 will be the basis for improving the program for Year 2.

References

[1] C. Speroni, "National Science Foundation's International Research Experiences for Undergraduates: A Comparative Analysis of the IRES and REU Programs," National Science Foundation, Alexandria, VA, 2021.

[2] D. B. Knight, N. Sanderlin, and K. A. Davis, "Assessing the impact of IRES on researchers, research outcomes, and students: A case study approach," School of Engineering Education Faculty Publications., Paper 78., 2020. [Online]. Available: https://global.eng.vt.edu/Resources/IRES.html

[3] H. Thiry, T. J. Weston, S. L. Laursen, and A.-B. Hunter, "The Benefits of Multi-Year Research Experiences: Differences in Novice and Experienced Students' Reported Gains from Undergraduate Research," *CBE—Life Sci. Educ.*, vol. 11, no. 3, pp. 260–272, Sep. 2012, doi: 10.1187/cbe.11-11-0098.

[4] E. Seymour, A. B. Hunter, S. L. Laursen, and T. DeAntoni, "Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study," *Sci. Educ.*, vol. 88, no. 4, pp. 493–534, 2004, doi: https://doi.org/10.1002/sce.10131.
[5] R. Taraban, E. Prensky, and C. W. Bowen, "Critical factors in the undergraduate research experience," in *Creating effective undergraduate research programs in science*, New York, NY, US: Teachers College Press, 2008, pp. 172–188.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. 2246339.

Sangjin Ryu

Dr. Sangjin Ryu is an Associate Professor with the Department of Mechanical and Materials Engineering of UNL. He holds his Ph.D. in Mechanical Engineering from M.I.T. and his B.S. and M.S. degrees in Mechanical Engineering from Seoul National University, South Korea. Dr. Ryu was awarded UNL College of Engineering Holling Family Distinguished Teaching/Advising/Mentoring Award (2024), UNL College Distinguished Teaching Award (2019), UNL College of Engineering Holling Family Master Teacher Award (2019), and Outstanding Faculty Award from UNL Pi Tau Sigma (2019).

Jessica Deters

Dr. Jessica Deters is an Assistant Professor of Mechanical and Materials Engineering and Discipline Based Education Researcher at UNL. She holds her Ph.D. in Engineering Education and M.S. in Systems Engineering from Virginia Tech.

Jonathan Janecek

Jonathan Janecek is a fourth-year electrical engineering student at UNL, with a focus in circuit design and embedded systems. He is a math and engineering tutor at UNL and spent this past summer as a participant in the 2024 NSF IRES Japan program gaining research experience at Toyohashi University of Technology designing a portable device for pathogen detection. On campus he is an active member in the Aerospace and Institute of Electrical and Electronics Engineers/Eta Kappa Nu (IEEE/HKN) clubs.

Christian Sunderland

Christian Sunderland is a senior student studying physics and data analytics at Nebraska Wesleyan University. He completed two months of interdisciplinary research in Toyohashi, Japan. He hopes to continue research of different physical fields before moving onto graduate school to study astrophysics.

Laurel Sky Wagner

Laurel Wagner is a senior undergraduate student studying chemical engineering at UNL. At UNL, she is an introductory chemical engineering teaching assistant, an executive officer in the UNL Society of Women Engineers, and a team lead in the University of Nebraska Engineers Without Borders Student Chapter. She was a visiting scholar in the 2022 University of California San Diego Advanced Materials Research Experiences for Undergraduates (REU), 2023 Materials REU at the University of California, Irvine, and the 2024 NSF IRES Japan program at Toyohashi University of Technology.

Rachael Wagner

Rachael Wagner is a biomedical engineering PhD student at UNL. Her research interests include medical devices, space technology, and surgical robotics. She graduated with a bachelor's from UNL in 2018 and worked at Virtual Incision in Lincoln, NE before pursuing a graduate degree.