Purdue-Tsinghua Undergraduate Research Dual Exchange: A New Programmatic Implementation for Enhancing Global Learning

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Introduction

Global learning continues to gain prominence in many engineering schools and degree programs. Yet among existing offerings, for-credit study abroad and exchange formats continue to overshadow programs that offer students global research or work sojourns. While such opportunities are particularly promising given their ability to provide students with experiential learning, usually on cross-cultural and interdisciplinary teams, a major challenge associated with implementing and scaling up these global research programs is the motivation of faculty and students from the participating countries and institutions.

In response to this challenge, Purdue University has developed and offered a team research program in engineering since 2010 that takes place at both its campus and the campus of Tsinghua University, the top engineering school in China, during the summer semester. In this paper we provide a detailed description of the two-way exchange program and summarize results from a systematic analysis of five reflective learning prompts that were administered to the student participants throughout the program (i.e., 1 pre-program, 3 mid-program, and 1 post-program). As further background for these efforts, we summarize relevant prior literature discussing strategies for scaffolding and assessing learning outcomes, both in general and specifically in the context of global engineering programs. Based on our preliminary results, we also discuss both benefits and challenges associated with this innovative programmatic implementation. Furthermore, we propose directions for improvement, with an emphasis on student recruitment, faculty involvement, and assessment of outcomes. This paper will likely be of interest to university faculty and staff who are interested in or already involved with programs that provide engineering students with opportunities for experiential learning abroad.

Background and Literature Review

To maintain America's global competitiveness in a financially uncertain and rapidly changing global economy, it has been argued that the American engineering workforce in 2020 should not only possess technical expertise but also professional skills, cultural awareness, and a global perspective[1,2]. Responding to such calls, many global engineering education programs have been created and promoted to provide global learning opportunities to American engineering students. Typical types of programs and experiences that are offered to engineering students include study abroad, globally-oriented class experiences, global projects, international internships, and international research experiences[3,4]. Study abroad experiences are often accomplished through short- or long-term sojourns, or bilateral exchange of students between universities. Some schools also offer global engineering courses that emphasize historical and cultural themes, sometimes through engagement with guest speakers.[3] Service projects with global dimensions are another prevalent program format. These program options vary according to factors such as duration, language requirements, context of work, extent of interactions with natives of the host country, and curricular status, to name a few. Information about a number of research abroad programs similar to our dual-exchange program have been published.[5]

About the Purdue-Tsinghua Undergraduate Dual-Exchange Research Program

Aligned with the larger trends noted above, the Purdue-Tsinghua Undergraduate Dual-Exchange Research Program (referred to as "the two-way program" in the remainder of the paper) was developed to leverage existing resources, build on sound prior scholarship, and dovetail with a clear set of educational research objectives. The two-way program is a team-oriented research program offered by the Purdue's Office of Professional Practice. Tsinghua University is one of the top ranked universities in China and widely regarded as the best in the field of engineering. The two-way program started in 2010 with receipt of a seed grant from Purdue's International Programs. Students from the two partner institutions form cross-cultural teams that undertake interdisciplinary research projects for a period of ten weeks. This paper describes the two projects offered during the summer of 2014, which were focused on big data and analytics in biomedicine. The projects' interdisciplinary spirit is justified and strengthened by the participation of faculty advisors from Purdue's Weldon School of Biomedical Engineering and Tsinghua's Department of Automation.

The dual exchange program is structured such that intensive research is first conducted in a Tsinghua University lab for five weeks, from early June to mid July. Typically, during the first phase of the project when the students are in Tsinghua they familiarize themselves with the domain knowledge and the data mining techniques they will be using in their research. The first author also has weekly conference calls with the students, and the students are instructed to ask their native Chinese professor for technical support. Next, the paired students travel back to Purdue University and continue to conduct their research for five more weeks. In the second phase of the project they apply the selected data mining methods. They are expected to produce results that could later be turned into conference presentations and/or scholarly publications. The summer semester provides a convenient time for both sides because neither the U.S. students' nor Chinese students' academic calendar is impacted. And in contrast to *one-way* study aboard or research programs, the dual exchange format offers the continuity of global learning experience for the American students even after their return from China. The students are also offered the opportunity to continue working on the project during the subsequent academic year, with a focus on manuscript preparation.

Research project topics are proposed by the first author and his domain collaborators at Purdue University. In the summer of 2014, four students participated in two data mining projects, which are the focus of the experiences discussed in this paper. The titles of the projects are "Plaque Vulnerability Characterization for Acute Coronary Syndrome using Photoacoustic Imaging Data" and "Feature Extraction in Analyzing Communication Sequence Data in Shared Medical Decision-Making Processes for Better Predicting Patient Satisfaction." After the project descriptions were developed and approved by the relevant Purdue personnel, they were sent to the first author's counterpart at Tsinghua for final approval. Once the descriptions were approved by both sides, the recruitment process was underway at both universities. From late March to May, the students were contacted by the international exchange and study abroad offices to deal with the international travel issues. The students also relied on their native counterparts to help one another prepare for basic living issues in each country.

As part of the two-way program the first author has contributed and supervised a number of big data biomedical analytics projects jointly with his Chinese counterpart. With modern

information-sensing technology, we are able to create large data sets in a short amount of time. These large data sets appear in many areas including meteorology and genomics, as well as business analytics. The real challenges lie in the management of such gigantic amounts of data, and more importantly, the analysis of such data, i.e., can we discover knowledge from the data and use the knowledge to aid intelligent decision-making? Meanwhile, to achieve this ultimate goal, it is critical to gain deep understanding of the contextual and geographic domain in which these large data sets are created – oftentimes in global settings.

Scaffolds for Global Learning and Reflection

Many strategies have been used to make global learning experiences more effective and meaningful to participating students, especially given the relatively large resource commitments they often entail. Among these strategies, scaffolding learning through reflection has been recognized as a particularly promising and effective approach to help students make sense of their experiences. In fact, encouraging student reflection can influence how students will later approach similar situations. John Dewey acknowledged that a great deal of learning occurs within a student's experience.[6] Later researchers developed models for learning based on individual learning experiences. For instance, the Kolb model for experiential learning relies on students reflecting on an experience in order for them to create new knowledge.[7] Jack Mezirow also realized that transformative learning springs from reflections.[8] He saw that new knowledge comes from students critically reflecting on their experiences, which lead them to challenge their assumptions and influence their future decisions.

Jennifer Turns and her research group have offered extensive insights regarding how reflection can positively impact students.[9] In their 2014 ASEE paper, they pose a hypothetical situation where three students reflect on a tedious homework assignment. One student wonders if she made a right choice picking her major, another ponders the real implications of the problems he worked on, and the third thinks about taking steps to make the next homework assignment more manageable. Each student faced the same challenging assignment, but their reflections took them to different mentalities that could affect their future performance.[9] Nonetheless, having students perform active reflection is not easy. Usually the reflections need to be an integrated and required component of the student's learning experience. Boud has also argued that in order for students to reflect successfully, the instructor must put considerable effort into scaffolding the reflective practice.[10]

Yet even when instructors build reflection on solid scaffolds, participating students often show considerable variation in their depth and breadth of reflection. In recognition of this fact, Chabon and Wilkerson have developed a framework to allow researchers to analyze the depth of student reflections based on four different levels.[11] If reflections lead to new knowledge, then it could be said that the depth of the reflection can indicate how well a student understands or is aware of a topic. Yet in addition to depth of reflection, open-ended reflection prompts may lead students to comment on a wide range of learning experiences and topics, particularly in a multi-faceted program such as the two-way research exchanged described here. Hence, the authors of this paper also looked beyond the levels of reflection framework. They were specifically inspired by Mohtar and Dare's prior efforts to study global competencies, with a focus on global technical, professional, and cultural learning outcomes.[12] These competencies have been used as a means to model students' global experiences in a variety of other programs at Purdue, as well as to help

guide the creation of assessments and reflective prompts to evaluate the extent to which students are indeed becoming more globally competent. These two frameworks were used to analyze and make sense of the data for this paper, as will be described next.

Methods

The major objective of this study is to analyze and report on the learning outcomes and levels of reflection evident in data collected from undergraduate engineering students participating in the two-way research program during summer 2014. The sections that follow provide further information about the participants, along with the data collection and analysis procedures.

Participants

Two American students, affiliated with the Global Engineering Alliance for Research and Education (GEARE) program, were selected to participate in the two projects. One was a Biomedical Engineering major and the other was in Electrical and Computer Engineering. Both were sophomore students. The two Chinese students were selected from about 10 students who applied for the internship. They were both juniors majoring in Automation at Tsinghua.

Data Collection

The reflective prompts used in this project were adapted from previous studies conducted by Purdue University's Global Engineering Program (GEP). This approach was adapted for the two-way program to help students reflect on their learning experiences while working on global service projects. The reflection data was also viewed as a means for the program to see what learning objectives and outcomes were being met. The first author administered the reflective prompts in a series that was intended to capture student learning and development over the project duration. The reflection prompts created and used in this study are given in Table 1.

More specifically, a series of five surveys were administered by the first author, who was the Purdue lead faculty member for the research internships. The pre-project reflection was sent to all four students one week prior to the American students' departure to China. The students were asked to submit the completed reflection before the American students' arrival. From early June to mid August, three mid-program reflections were completed by all four students. They were typically given 4-6 days to complete each round of reflections. The first was around June 20, the second was during the transition week, and the third was in early August. After the project, all four students were asked to complete a post-project reflection. All surveys were sent to the students and returned to the first author in an online format (i.e., via Word document files).

Table 1. Detailed Overview of Reflective Prompts

Reflection Stage	Reflection Prompts
Pre-Program Reflection	1. In general, what do you hope to learn and/or accomplish by the end of your summer research experience? 2. Identify and describe one specific goal for personal and/or professional development that you hope to achieve within the next 10 weeks. Be specific in how you expect to achieve this goal.

Mid-Program Reflection Entry 1	1. During the last two and half weeks, what is ONE significant challenge you SUCCESSFULLY faced or resolved? In your 1+ paragraph response describe the challenge, what you have learned from this experience, and reflect on how this experience might help you in the future 2. During the last two weeks and half, what is ONE challenge you have NOT been able to resolve? In your 1+ paragraph response describe the challenge, discuss what you have learned, or not learned, from this challenge, and reflect on how you will deal with this type of challenge in the future. 3. During the past 2 – 3 weeks, what is one trait/practice/behavior/way of life that you have observed in China that is most different from your native culture/background? In your 1+ paragraph response describe the trait/practice/behavior/way of life, discuss similarities/differences compared to your own culture/background, and reflect on how you reacted to this trait/practice/behavior/way of life. 4. Identify and describe one specific goal for personal and/or professional development that you hope to achieve before the end of the summer project.
Mid-Program Reflection Entry 2	1. During the last two and a half weeks, what is ONE significant challenge you SUCCESSFULLY faced or resolved? In your 1+ paragraph response, describe the challenge, discuss what you have learned from this experience, and reflect on how this experience might help you in the future. 2. During the last two and a half weeks (before you flew to the U.S.) what is ONE challenge you have NOT been able to resolve? In your 1+ paragraph response, describe the challenge, discuss what you have learned, or not learned, from this challenge, and reflect on how you will deal with this type of challenge in the future. 3. During the first week in the U.S., what is one trait/practice/behavior/way of life that you have observed in America that is most different from your native culture/background? In your 1+ paragraph response, describe the trait/practice/behavior/way of life, discuss similarities/differences compared to your own culture/background, and reflect on how you reacted to this trait/practice/behavior/way of life. 4. Identify and describe one specific goal for personal and/or professional development that you hope to achieve before the end of the summer project.
Mid-Program Reflection Entry 3	1. During the last three weeks, what is ONE significant challenge you SUCCESSFULLY faced or resolved? In your 1+ paragraph response, describe the challenge, discuss what you have learned from this experience, and reflect on how this experience might help you in the future. 2. During the last three weeks, what is ONE challenge you have NOT

	been able to resolve? In your 1+ paragraph response, describe the challenge, discuss what you have learned, or not learned, from this challenge, and reflect on how you will deal with this type of challenge in the future.
	3. During the last few weeks in the U.S., what is one trait/practice/behavior/way of life that you have observed in America that is most different from your native culture/background? In your 1+ paragraph response, describe the trait/practice/behavior/way of life, discuss similarities/differences compared to your own culture/background, and reflect on how you reacted to this trait/practice/behavior/way of life.
	4. Identify and describe one specific goal for personal and/or professional development that you hope to achieve before the end of the summer project.
Post-Program Reflection	1. During the last 3 months, what is ONE significant challenge you SUCCESSFULLY faced or resolved? In your 1+ paragraph response, describe the challenge, discuss what you have learned from this experience, and reflect on how this experience might help you in the future.
	2. During the last 3 months, what is ONE challenge you were NOT been able to resolve? In your 1+ paragraph response describe the challenge, discuss what you have learned, or not learned, from this challenge, and reflect on how you will deal with this type of challenge in the future.
	3. How do you think your summer research experience has helped you grow personally and/or professionally? In your response, please discuss your most significant areas of growth.
	4. Identify and describe one specific goal for future personal and/or professional development that builds on your summer research experience.

Data Analysis

After the program was completed the reflective responses were analyzed by the four co-authors. They divided into pairs and used a priori codes based on both the technical-professional-cultural (TPC) and levels of reflection coding frameworks to analyze the student responses. The authors first examined one American and one Chinese student to sensitize them to the framework and then later collaborated with their partner to seek coding alignment. After becoming sensitized to the analysis, the authors analyzed the final two students and finalized all coding decisions.

Since participation in the two-way program was a global experience for all students involved, we expected to see reflections regarding global technical, professional, and cultural aspects. Yet while the research experience was within a global context, we also found evidence of more general technical, professional, and cultural learning that developed independently of the global location and context. Therefore, we expanded the framework to distinguish between global learning and non-global learning during the two-way exchange experience. The final set of codes and their descriptions are given in Table 2.

Table 2. Global Technical, Professional, and Cultural Competencies Framework

Code	Representative Examples Adapted from Mohtar and Dare[12]
Global Technical	I.1 An awareness of varying regulations, codes of practice, standards, technical specifications, testing/inspection procedures, environmental regulations, and systems of measurement between countries and regions I.2 Familiarity with the concept of a "global product platform" I.3 The ability to apply familiar concepts to unfamiliar, real-world problems I.4 The ability to use design tools to solve engineering problems[12]
Global Professional	II.1 The ability to adapt to cultural norms in a professional arena and act appropriately II.2 The ability to make ethical and socially responsible decisions in the context of a culture divergent form my own. II. 3 The ability to analyze problems from a different cultural frame of reference II.4 The ability to communicate professionally in a culturally appropriate manner[12]
Global Cultural	III.1 The ability to practice social and cultural responsibility, e.g. resource sustainability III.2 Proficiency in a second language III.3 The ability to be cross-culturally adaptable/flexible III.4 The ability to contribute to a culturally-diverse team[12]
Technical	IV.1 An awareness of regulations, codes of practice, standards, technical specifications, testing/inspection procedures, environmental regulations, and systems of measurement IV.2 The ability to apply familiar concepts to unfamiliar, real-world problems IV.3 The ability to use design tools to solve engineering problems[12]
Professional	V.1 The ability to adapt to in a professional arena and act appropriately V.2 The ability to make ethical and socially responsible decisions V.3 The ability to communicate professionally
Cultural	VI.1 The ability to practice social and cultural responsibility, e.g., resource sustainability VI.2 The ability to be adaptable/flexible VI.3 The ability to contribute to a team

As noted earlier, Chabon and Wilkerson have developed a framework to allow researchers to understand the depth of student reflections. Their framework includes four distinct levels of reflection. In their work, Chabon and Wilkerson connect the level of reflection with how well the students have come to understand a given topic.[11] Since there were some student reflections that did not fit in the Chabon and Wilkerson framework, the authors decided to give the framework a pre-reflective level, called Learning Goals. This level primarily dealt with the students discussing their future learning goals or expectations, either within or beyond the two-way program. Each

level builds off the other and Chabon and Wilkerson acknowledge that student reflections can be coded with co-occurring levels. The levels are summarized in Table 3.

Table 3. Depth of Reflection Framework[11]

Code	Description
Learning Goals	I.1 Student discusses the expectation of learning something or wanting to learn something in the future.
Descriptive	II.1 Student develops acquisition of new content from significant learning experience. II. 2 Evidence of gaining knowledge II. 3 Making sense of new experiences II. 4 Making links between old and new knowledge
Empathic	III.1 Demonstrate thoughts about or challenges to beliefs, values, and attitudes of self and others III.2 Self-projection into the experiences of others III.3 Sensitivity towards the values and beliefs of others tolerance of differences
Analytic	IV.1 Demonstrate application of learning to a broader context of personal and professional life. IV.2 Use of observations and discussions to examine, appraise, compare, contrast, plan for new actions, or propose remedies to use in and outside of structured learning experiences
Metacognitive	V.1 Demonstrate examination of the learning process V.2 Show what & how learning occurred V.3 Show how new knowledge altered existing knowledge

Findings

After the four authors finished their data analysis, the codes were tallied and summarized as given in Table 4. The codes were tallied as a way of getting a more global sense for what kinds of topics students most frequently commented on, while also providing evidence for the extent to which student responses showed the various levels of reflection.

Table 4. Summary of Student Outcomes by Topic Area and Levels of Reflection

GTCP Framework	# of Coded Instances	Levels of Reflection Framework	# of Coded Instances
Global Technical	0	Learning Goals	21
Global Cultural	26	Descriptive	39
Global Professional	13	Empathic	11
Technical	31	Analytic	26
Cultural	1	Metacognitive	1
Professional	15		

The two codes appearing most often in the GTPC framework were technical (31 instances) and global cultural (26 instances). This is perhaps not surprising, since the nature of both the two-

way program and reflection prompts likely increased the probability that student responses would frequently fall in these two categories. We also found frequent mention of learning goals (21 instances), as well as descriptive (39 instances) and analytic (26 instances) types of reflections. Here again we observe that the reflection prompts themselves likely guided students toward these types of reflective statements. Even so, the details and personal aspects of the reflections provide insight into the meaning of the experience, including how the students plan to use their new knowledge in the future. The following sections of the paper present student reflection data exemplifying the codes used in our analysis. The authors of the paper have taken care to report results such that all of the program participants are represented in the findings. The participants are given pseudonyms to protect their identity, in accord with procedures for this project approved by Purdue University's Institutional Review Board (IRB).

Global Technical and Technical Codes

When the students who participated in the two-way program reflected on their experiences, they only talked about the technical aspects in a decontextualized sense. Indeed, the largest number of comments about the students' challenges and accomplishments in this program were related to technical topics. For example, in her initial pre-project reflection Mei discussed some specific kinds of technical learning she hoped to experience through her participation in the program:

> *Firstly, the project is about analysis of medical images, a branch of bioinformatics which I know little about. I hope to learn more in this field and thus find which specific subfield I am most interested in. Secondly, though the classify techniques are already mature, it is still hard to improve the accuracy and computing speed in specific question. Thus I want to get more familiar with how to use those techniques properly and efficiently in actual problem. (Mei, Pre-Program, Question 1)*

Yet despite the learning experience also being global in nature, the students did not seem to engage with the global technical aspects of what they were learning, e.g., local differences in technical work practices, styles or cultures of research, standards or regulations, etc.

Global Cultural and Cultural Codes

Culture was the second most often discussed topic, and in all but one instance was discussed from a global rather than non-global standpoint. Two representative examples of reflection comments coded as global cultural can be found in mid-project excerpts from Andrew and Song:

> *One practice that I really admire in Beijing is how much everyone prefers to use the public transportation (bicycles, subways and buses.) I get really frustrated when two people who live really close by in US/Kuwait/India and have the same destination, take two different cars and spend double the amount of resources to fulfill their journey. There is A LOT less of that practice here. I was really happy to see this! I used to be the odd one out to ride bicycles wherever I've lived before. It's good to be a part of the majority now. Bicycling, taking buses and subways are very efficient ways of travelling. (Andrew, Mid-Program 1, Question 3)*

> *People here are more likely to smile as greetings when facing with stranger, warming our heart. However, it's will be oddness to do this in China especially on the road. Besides, many people will initiative to help you when you get lost. I enjoy these habits and I will practice these behaviors when I back in China. In addition, friends here are only talk about hobbies and problems facing. They wont make comments on ones private things. I like these and behave in this way before. (Song, Mid-Program 3, Question 3)*

These two remarks begin to capture the kinds of global cultural themes most often discussed by participants, ranging from day-to-day issues such as transportation experiences to observations and learning about cross-cultural communication styles. On the other hand, only one reflection comment was coded as a general cultural experience, which specifically described how Andrew's love of the outdoors impacted his experience abroad:

> *I am a very outdoorsy person. On a few days, the pollution [in Beijing] makes it really hard for me to breathe. I get tired easily on bad days and don't get to exercise or travel as much I wish I would. I don't get bothered by the heat as much as I get with how thick the air is sometimes. (Andrew, Mid-Program 1, Question 2)*

Global Professional and Professional Codes

Some reflections were coded for more than one learning outcome. This is not surprising because developing global technical, professional and cultural skills often go hand and hand and can be seen as a result of one larger learning experience. In fact, discussing multiple categories of outcomes and using multiple levels of reflection in a single response may provide evidence for greater breadth and depth of learning. The following excerpt from one of Kim's reflections was coded for both global cultural and global professional themes. Specifically, she describes how she overcame the language barrier of working with Chinese colleagues while developing global professional skills such as cross-cultural collaboration and communication:

> *I think the biggest challenge I have faced during this summer was the language barrier. At first, I had a very hard time communicating with the Chinese students, even though their English was good. It was hard to talk about everyday things, let alone the advanced math and concepts we were trying to work on. However, as the summer progressed, we started to understand each other both with regards to the research and everyday life. It became collaboration rather than two people working mostly individually. It took a lot of patience at first; however, it became a great experience and friendship. I have learned how important communication is to progress in a research project. Our progress was so much more when we could work together and understand each other. As both research projects and companies now require collaboration between citizens of different countries, I learned how to adapt my communication skills to suit the situation. (Kim, Post-Program, Question 1).*

Professional skills and goals were sometimes also discussed more generally, without explicit mention of global context. For instance, Mei described how the research experience helped her confirm her desire to pursue her PhD:

> *I think it's a little bit exaggerated because two month's summer research may not able to change one's goal for future personal / professional development. But the experience truly changes my view of PhD life. After talking with professors and students in the lab, I'm now more clearly about how to do well in research and which kind of life is more fitted to me. (Mei, Post-Program, Question 4)*

Depth of Reflection Analysis

As summarized above, the authors found that the students primarily reflected on their learning experiences in Descriptive and Analytic modes, while Empathic reflections were less common and Metacognitive reflection only occurred once. Discussions of learning goals were also frequent. Below are some examples and highlights for each level, beginning from least reflective to most reflective. It should also be noted that Chabon and Wilkerson's framework allows for multiple levels to coexist within a given student response[11]. The authors were deliberate in trying to code for all applicable levels when analyzing each individual idea expressed by the students.

Learning Goals

As stated previously, Learning Goals were identified as a distinct "pre-reflective" code where the student discusses the expectation of learning something or wanting to learn something in the future. Instances of this code most frequently occurred within the pre-program reflections and also in the fourth question of each prompt. Mei's preceding remarks about what she hoped to learn in both technical and cultural terms is one good example of a learning goal. Another representative example can be found in Kim's post-program reflection:

> *I hope to continue to use my intellectual curiosity and independence that I have learned from this summer and apply it to my internship, future research, and schoolwork. I believe that this will allow me to learn a ton more in my future endeavors. I hope to continue to grow my communication skills and continue to develop the professional relationships that I have made during this program. I believe this program has allowed me to grow both personally and professionally, and I am excited to apply this skill-set in my future career. (Kim, Post-Program, Question 4)*

Note that in such instances students primarily listed their expectations for future learning. To be considered reflective, the responses would have to show some evidence that the students were trying to make sense of new knowledge and explicitly state that they learned something new.

Descriptive Level

The descriptive codes were the most prevalent, since they are the least comprehensive of the codes. The descriptive level usually deals with the acquisition of new knowledge, including

associated sense-making. Notice as we revisit this descriptive reflection from Andrew how he explained making sense of how the Chinese move from place to place:

> *One practice that I really admire in Beijing is how much everyone prefers to use the public transportation (bicycles, subways and buses.) I get really frustrated when two people who live really close by in US/Kuwait/India and have the same destination, take two different cars and spend double the amount of resources to fulfill their journey. There is A LOT less of that practice here. I was really happy to see this! I used to be the odd one out to ride bicycles wherever I've lived before. It's good to be a part of the majority now. Bicycling, taking buses and subways are very efficient ways of travelling. (Andrew, Mid-Program 1, Question 3)*

Song also acknowledged that he is learning something new from his research experience in the U.S., while his final statement helps show how he made sense of his experiences in the lab:

> *The challenge we face now is how to select the variables from the communication between the patients and the physicians to evaluate the physicians' behavior. From this challenge, I learned that how to handle a new problem with my partner. We made research individually and had brainstorming together. During the process of discussion, we came up with new ideas. It's cool! I will deal with the problem through the team work and individual hard working. Besides trying different methods maybe helpful to solve it. (Song, Mid-Program 1, Question 2)*

Empathic Level

Empathic level reflections were the second rarest reflection category, appearing just 11 times in the coded data set. This level of reflection usually appeared in discussions of cultural issues, which often involves needing to be sensitive to others and viewing situations from others' perspectives. Notice here how Kim's response involves putting herself in the shoes of the Chinese and challenging her notions of American habits. This offers clear evidence of the Empathic level, but more importantly notice that there is no future projection or appraisal occurring. Without those elements, her response can at most be considered Empathic but not Analytic or higher:

> *One thing I've noticed is that people seem to be much more laid back in China versus America. Also, everyone interact with each other very nicely and, in general, the Chinese people seem much friendlier than people in the U.S. Whether we are in a rush or not, Americans tend to speed walk everywhere and generally be impatient. On campus, I find myself generally passing people, whether I'm walking or biking somewhere. Also, even though I can't speak Chinese, it seems as though people are much more helpful and kind to each other. On the train, a man was sitting next to a family. One of the family's little kids reached for his popcorn, and he ended up sharing the bag with the little child. I highly doubt this would happen in my culture. In the New York City or Chicago subway, I feel like the pace the people take is much faster than here.*

The slower pace of life is nice, but I find myself walking as fast as possible, even if I have no real time that I have to be somewhere. It's a hard thing to adjust to sometimes. At first it was a little frustrating getting stuck in a mob of people not walking very quickly. However, I've been adjusting and I'm becoming used to this more relaxed pace of life. (Kim, Mid-Program 1, Question 3)

Andrew's response also mirrors Kim's in the sense that he puts himself in the shoes of his Chinese colleagues, but he also showed increased sensitivity to how the Chinese students were adjusting to living abroad:

I was really worried about how the Chinese students were going to settle in my house. It was not the most comfortable place to live in. I have tried to help them as much as possible, and they seem to content with their place of living. Since I was kind enough to give them a free place to live, they have been very kind to me too. Trusting someone with your place with your place is a great and satisfying thing to do. (Andrew, Mid-Program 3, Question 1)

Analytic Level

Analytic was the second most common level of reflection. The main distinction from the previous levels is that an Analytic response deals with future projections, comparisons, and appraisals of knowledge. Notice that Song's response includes an appraisal of how his current knowledge would be used within the context of his research experience:

Until now, I still face the challenge that how to get more information from the originate data and minimize the forecast error of the linear model. I have tried to use different methods and different dimensions of the data we have to build the linear model. However, the results we got are unpleasant. On the other hand, the process of dealing with the challenge is interesting. And we learn to look at the problem from different views. The next step I will take is trying new method to organize the data and use nonlinear method. (Song, Mid-Program 2, Question 2)

As another example, it is worth reviewing Andrew's response to Mid-Program 1, Question 3:

One practice that I really admire in Beijing is how much everyone prefers to use the public transportation (bicycles, subways and buses.) I get really frustrated when two people who live really close by in US/Kuwait/India and have the same destination, take two different cars and spend double the amount of resources to fulfill their journey. There is A LOT less of that practice here. I was really happy to see this! I used to be the odd one out to ride bicycles wherever I've lived before. It's good to be a part of the majority now. Bicycling, taking buses and subways are very efficient ways of travelling. (Andrew, Mid-Program 1, Question 3)

Notice how the first two ideas are Descriptive (gaining new knowledge and making sense of it) while the final comment is an appraisal of his new knowledge, making this passage Analytic. This coexistence of codes is to be expected when utilizing Chabon and Wilkerson's framework.

Metacognitive Level

Evidence of metacognitive reflection only occurred once. Perhaps due to the high-level nature of the code, the example used also exhibits lower levels of reflection. To be considered Metacognitive, a student must examine and question his/her way of thinking. In the response below, note that Mei finally moved into the Metacognitive level toward the end of her response:

> *In the last two weeks, I mainly studied the theory of MCR. As I have never worked on that before, it's kind of hard for me to choose what is important to study for the project, and what should I study first. However, after two weeks' study, I feel clearer about how to study something new. First, I can find a good review paper on my focus, and basically learn the method and its advantages and limitations. Next, I can look some papers of this field to see how the method can apply to real questions. And finally, I can see some code about the method. Studying code directly is the most clear and detailed way to study some method, and during this process, I will find some questions I need further explore. This experience helps me improve my self-learning ability. It will help me a lot to study something new more quickly and be able to use them. (Mei, Mid-Program 2, Question 1)*

There may be multiple reasons why only Mei delved so deeply in this passage, although she certainly could have gone even deeper. Yet as Chabon and Wilkerson (and others) have commented, deep reflections may require considerable instructional scaffolding as well as a high degree of comfort and rapport between the student and the instructor.[10,11]

Discussion and Conclusions

Through analysis of student reflection data, the authors have presented evidence of a variety of both global and non-global learning occurring in the context of a two-way research abroad program. Congruent with the larger program design, technical and global cultural learning outcomes were the most prevalent categories of learning, although professional and global professional themes also appeared frequently. Further, the program experience and associated reflection prompts appeared capable of encouraging students to comment on their learning goals and engage in descriptive and analytic reflection. Some evidence of empathic reflection was found mainly in comments about cultural learning, while metacognitive reflection was very scarce.

Based on our findings, additional scaffolding could potentially help guide students to more intentionally develop and reflect on a wider range of desirable learning outcomes, preferably aligned with a clear and explicit set of learning goals for the two-way program. Indeed, through our analysis we tentatively observe that the Purdue and Tsinghua students tend to have different learning goals related to their participation. Future development of the two-way program may

need to consider how to specifically target a core set of learning outcomes, while at the same time allowing diverse students to identify and pursue their own specific learning objectives.

Enhanced scaffolds for the program experience might include structured training sessions before and during the program, activities designed to support specific kinds of learning (including cross-cultural as well as technical), intensified interactions with diverse students and faculty, and/or more framing and guidance on the reflective learning process. Indeed, such scaffolds may help address the observed lack of empathic and metacognitive reflection among participants, while helping to make visible other learning objectives and outcomes in the program. The researchers acknowledge that the length of the responses is often proportional to the depth of reflection. Hence, additional scaffolding may influence the types of prompts used in future program iterations, including encourage students to be more open and comfortable in more deeply reflecting on their experiences. The authors expect that as more students take part in the program, having more reflective data will develop a clearer understanding of the full range of learning outcomes among students in the program.

Since it is of interest to sustain and grow this dual exchange program, the results of this analysis are important to improving the effectiveness of future recruitment efforts. For the program cycle of summer 2015, the development of the project descriptions began earlier and the descriptions were released to the students on both sides in January 2015. With the earlier start of the recruitment, the first author expects to get more student applications and plans to be more actively involved in the selection process. As stated previously, faculty involvement is important. In an effort to elevate the program to a more sustainable and impactful level, the first author has approached several professors in the other areas of data analytics such as econometrics and computational biology. As a result, more than one professor will be able to lead the big data analytics projects emphasized in the two-way program while more broadly helping to enhance the students' learning experiences. We will build on this momentum and approach other biomedical engineering faculty and engineering faculty in general. Both Purdue and Tsinghua have showed continued interest in scaling up this program.

We see this small-scale study pointing to some additional directions for scholarly work. For example, we see considerable promise in the continued development and use of the GTPC framework as a means of determining what students are learning from their global experiences. We also expect to build a deeper understanding of student learning as the number of participants increases over time. We also intend to perform further analysis to determine whether there are any significant co-occurrence patterns between the GTPC and levels of reflection categories. It may be the case, for example, that students tend to reflect more or less deeply on certain kinds of learning outcomes. Finally, we remain intrigued by the challenge of encouraging engineering students to reflect in empathic and metacognitive terms, a process which may be made more difficult by the types of students typically found in such engineering programs. We hope that the continued operation and vitality of the two-way program will allow us to collect more reflection data, which will in turn generate answers to some of the questions and issues raised in this paper.

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