AC 2011-1256: DEVELOPING THE GLOBAL BIOMEDICAL ENGINEER THROUGH A 12-MONTH INTERNATIONAL UNDERGRADUATE RESEARCH EXPERIENCE IN THE U.S. AND CHINA

Barbara Burks Fasse, Georgia Institute of Technology

Barbara Burks Fasse is an educational psychologist and senior research scientist in the Coulter Department of Biomedical Engineering at Georgia Tech. Dr. Fasse studies the efficacy and value of student-centered learning initiatives– specifically Problem-Based and Project-Based Inquiry Learning– in classrooms, instructional labs, and undergraduate research experiences. She joined the BME faculty in 2007 following ten years in Georgia Tech's College of Computing where she was a member of the NSF-funded Learning By Design Problem-Based Learning curriculum development and research project. She has also conducted an NSF-funded ethnographic study of learning in a problem-driven, project-based bio-robotics research lab at Georgia Tech. Dr. Fasse is a member of the Science Learning: Integrating Design, Engineering, and Robotics (SLIDER) interdisciplinary research team.

Paul Benkeser, Georgia Institute of Technology

Dr. Paul J. Benkeser received the B.S. degree in Electrical Engineering from Purdue University in 1981 and the M.S. and Ph.D. degrees in Electrical Engineering from the University of Illinois in 1983 and 1985 respectively. His current position is Professor and Associate Chair for Undergraduate Studies in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University. Dr. Benkeser is an American Institute of Medical and Biological Engineering (AIMBE) Fellow, a member of the Biomedical Engineering Society (BMES), a member of the American Society for Engineering Education (ASEE) and a senior member of the Institute for Electrical and Electronics Engineers (IEEE).

Developing the Global Biomedical Engineer through a 12-month International Undergraduate Research Experience in the U.S. and China

Abstract

The China Undergraduate Research Experience (CURE) is an NSF-funded research project offering undergraduate students three consecutive semesters of lab research, including an integrated international component. The goal of CURE is to provide undergraduate students with an international research experience that offers them a global perspective on research challenges and opportunities in the field of biomedical engineering while enhancing their skills in scholarship and innovation through research. A related objective is to motivate students not only to enter graduate studies, but also to enroll in a graduate program with an international component. A third goal is for these undergraduate students to serve as a type of shared asset linking the work, communication, and cultures of the three institutional partners.

For this first report of the three-year project, the attention is limited to what we learned about facilitating the international module of the program from the first cohort's experiences. In future reports we will widen our lens to include the overall effects of the 12 months of undergraduate research.

Introduction

The Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University has been successful in encouraging and training its undergraduate students to pursue graduate studies. Approximately 30% of the graduates from its B.S. program continue their studies in science and engineering fields in graduate school every year. We believe one of the factors that contribute to our success in keeping our graduates engaged in science and engineering may be the self-conscious steps we take to encourage early and long-term research experiences for our undergraduates.

The China Undergraduate Research Experience (CURE) expands our models for training undergraduate researchers to address the need to educate a globally-engaged workforce in science and engineering by integrating an international research experience within twelve consecutive months of research. To address this goal, we leveraged the partnership between the biomedical engineering departments at three internationally renowned institutions, Peking University (PKU), Emory University (Emory) and The Georgia Tech Institute of Technology (Georgia Tech). At the core of the Georgia Tech/Emory/PKU partnership is collaborative research between investigators at the three institutions. In this paper, we will present what we learned about the international semester of CURE as enacted by its first cohort while in residence at PKU in Beijing. We will focus on implementation of CURE in the PKU labs.

The CURE Program

CURE is a yearlong program designed to involve qualified students in biomedical engineering research projects between collaborating faculty at Georgia Tech/Emory University in the United States and Peking University in China. The primary goal of this program is to immerse undergraduate students in the research community by giving them a full year of lab experience that also offers a global perspective on research challenges and opportunities in the field of biomedical engineering. It is our hope that this will inspire students not only to enter a graduate program, but also to seek a program with an international component.

An additional, and equally important, goal of CURE is to build relationships between personnel in the three collaborating institutions by linking the collaborators *and* their work with each other through these students. We conceptualized the participating student as a resource that would be shared by the collaborating laboratories and, thus, would be prepared by the Georgia Tech Tech/Emory PIs and mentors to move relatively seamlessly into the work of the partnering PKU labs and vise-versa when the student reentered the Georgia Tech/Emory lab at the end of the summer. In this model, the student as shared asset accrues value to him/herself and to the work of the lab as he/she moves through the twelve-month program and, at the same time, becomes a human link between the labs, universities, the developing body of work, and the collaborating staff.

Key features of the CURE program are:

- a challenging research project, with co-principal investigators at PKU and Georgia Tech/Emory, in an area related to biomedical engineering;
- a three-term research experience, with spring and fall semesters' research conducted in the Georgia Tech/Emory investigator's laboratory and the interim summer term's research conducted in the collaborating PKU investigator's laboratory;
- pairing each student with a PKU faculty advisor and Georgia Tech/Emory faculty advisor as well as a graduate student mentor modeling the cooperative international tenor of the PKU/Georgia Tech/Emory partnership for the student;
- lodging, meals, and a travel allowance for participants during their stay at PKU;
- social and cultural interaction between the student participants and their graduate mentors;
- academic credit for their research during the spring and fall semesters at Georgia Tech and Emory;
- housing in either PKU dormitories or in private apartments adjacent to the PKU campus during the 10-week summer in China;
- the same health care insurance the semester-abroad undergraduates purchase;
- the financial incentives offered by CURE are designed to be competitive with other internship and research experiences available to BME students in order to enable the recruitment of some of the best available students.

The first cohort, CURE 2010, began the program with a semester-long research experience for academic credit in Georgia Tech or Emory laboratories during the Spring 2010 semester. This was followed by 10-weeks of research in the PKU collaborator's laboratory in China during the

summer of 2010 which is the focus of this report. Upon return to the United States, the CURE 2010 cohort completed the program during the Fall 2010 semester in the Emory or Georgia Tech labs.

Research Design

Our qualitative methodology uses case study design (Fasse, 1993; Merriam, 1988; Yin, 1984) to answer first-round research question: what could we learn from the first cohort about CURE's potential for promoting interest in graduate school- specifically with an international component, developing the globally-engaged biomedical engineer, and linking partnering international universities through undergraduate researchers as a shared asset? The participants' cases-- their individual and collective experiences—form the basis and unit of study (Stake, 2006). Since case study design does not lay claim to methodology unique to itself, we are drawing from standard qualitative methods such as participant observation, interview, and self-report accounts. We have developed the thick description (Geertz, 1983) necessary for authentic understanding of a social phenomenon by triangulating a variety of sources in order to assure reliability, dependability, and authenticity (Goetz & LeCompte, 1984; Lincoln & Guba, 1985; Measor, 1985; Merriam, 1988; Spradley, 1980). Data sources were compared within each subject, between subjects, and across sources to develop a thorough understanding of CURE as enacted.

Constant comparative methodology (Glaser & Strauss, 1967) was used to concurrently collect and analyze data while the subjects were engaged in the activity which then generated more questions and opportunities for clarification submitted at that time and after they left the field. In this first round of analysis, data coding centered on outcomes related to the fidelity of the first implementation of the international component of CURE. As is consistent with a qualitative research approach, a control group was not used to compare the data, instead the comparisons are within and across the unit of study: the cases.

Methods

Assessment of the CURE program is of interest for its direct impact on the individual student participants as well as its broader implications on the participation and preparation of both undergraduate and graduate students in global learning experiences in biomedical engineering laboratory settings in general.

The goal of the first round of assessment reported here was to identify lessons learned for improving implementation in subsequent iterations of this three-year research project. We begin with examining the international component because it is the linchpin of CURE.

Participants

Nine Georgia Tech BME undergraduate students were chosen from a pool of twelve applicants to participate in CURE 2010: three females, six males. Their ages ranged from 18 to 21. Projected graduation dates for the cohort ranged from May 2011 to May 2013.

Four of the participants are Chinese-Americans with some relatives living in Korea and/or Taiwan. Three students are of Anglo-American heritage. One student is Chinese-Middle Eastern-American. One student is Malaysian.

Chinese language skills ranged from novice to expert arrayed between one novice speaker whose only language training was a single semester of Chinese prior to the trip and three fluent students who could read and write Mandarin in addition to speaking it. Seven students had taken a least one Chinese language course at Georgia Tech. Four of the Asian-American students had grown up with various amounts of Chinese, Mandarin, and/or Korean spoken in their homes. Collectively, they were able to make their way around Beijing until those with less language facility picked up enough useful phrases and terms for independence.

The students reported volunteering for this project for a variety of reasons. Expecting to learn more about their research project, they also hoped to try out and improve their Chinese language skills, explore the Chinese culture, and build their resume. Several of them welcomed an excuse to learn more about the land of their family's heritage. Most acknowledged the lure of being paid to (a) do research and (b) travel to China.

All participants were made explicitly aware that they were the subjects in a funded research project studying the effects of their participation in CURE. They signed IRB-approved consent forms as acknowledgement of their understanding and agreement to participate as well as to approve of the use of their artifacts as data.

Setting

CURE is adapted to the calendar year, thus, the international component occurs during the summer semester, inserted between spring and fall in the US labs. This report represents the first CURE cohort's residence in Peking, China, during the summer semester, May through July, 2010.

As outlined in the program description above, the students lived in an international dorm on the PKU campus. They were assigned to partnering PKU labs for conducting research. The labs were scattered all over the campus within a short walk of each other and the dorm, except for one student whose lab was located in an off-campus medical facility necessitating a 30-minute bus ride.

The CURE students assumed a normal student life while in China. When not in the labs, their time was their own. They moved around the city individually, in sub-sets, and as a large group. They were free to socialize, sightsee, and do whatever it is that they would normally enjoy doing with their off-duty time. They were paid a stipend which they reported comfortably covered their expenses for meals, admission to historical sites and cultural events, entertainment costs, and local transportation, allowing them to take advantage of the opportunities offered by life in this unique city.

Data Sources

The data sources for this report consist of the students' weekly CURE journals triangulated with observations and field-notes from an extended site visit to PKU as well as informal and formal interviews conducted in the field and after returning. For the full project, we were interested in understanding what was going on-- professionally and personally-- in different realms of the international component of the experience, that is, their observations of and adaptation to:

- life among the Chinese culture and people;
- living with their CURE colleagues;
- their research as planned and as enacted;
- the way work is conducted in the PKU labs (as compared with and in contrast to their US lab) ;
- the nature of collaboration with PKU lab personnel.

For this report, we will concentrate on the last three that deal specifically with implementing CURE in the PKU labs.

Site visit observations in the field: A weeklong site visit occurred four weeks after the students arrived in Peking allowing them time to settle into their new "home" without distraction. Eight students were present for the site visit; the ninth student was in Shanghai for a family reunion throughout the week.

CURE Journal: Weekly face-to-face interviews with the students were impractical given the geographical distance, time zone differences, and technological limitations (e.g., unreliable and expensive video-chat connections) between the US and China. However, post-treatment accounts are less than desirable because they depend on accuracy of memories and tend to be heavily influenced by the final experiences thus introducing three of Schacter's (1999) seven memory flaws: transience (decreasing accessibility of information over time), absent-mindedness (inattentive or shallow processing that contributes to weak memories), and blocking (temporary inaccessibility of information that is stored in memory). To control for this, the CURE journal was designed to serve as a series of in-the-minute, real-time "interviews" in which students were given a prompt as a topic for focusing each week's "discussion". It was developed as a tool to increase the validity of the data by avoiding post hoc interviews or surveys that would be limited by recollections and re-creations. Additionally, communicating regularly through the journals linked Georgia Tech to the students allowing us to remotely monitor their adjustment and safety in real-time in the event that emergency intervention might be required. The prompts also provided a therapeutic tool for the students as a neutral place to vent their frustrations, share their triumphs, and distill their experiences.

> Student L*: Thanks for having us do these journal updates. It's been nice to have someone to talk to (and sometimes vent to as well).*
> Student D: *the journal entries… did help me reflect on my trip in a way I wouldn't have been able to do alone.*

Students were told to conceptualize the journal as a personal conversation with the first author of this paper in the form of an informal document in which format, style, and writing mechanics were suspended-- "simply download your thoughts through your fingers and into your

keyboard". The purpose of the journal exercise was not to elicit well-crafted written documents, but, instead, to encourage depth and breadth of reflection as well as willing compliance. Please note that the supporting data presented in this paper are verbatim from the journals with spelling, punctuation, and grammatical choices as written by the participants.

The thirty-minute assignment was to thoughtfully address the week's topic each Sunday in a written Word document. These were then emailed to me each week individually. As the journal documents arrived, they were analyzed as data-- that is, they were logged, coded, interpreted. A individual response was sent to each student, often for clarification related to the data as submitted. Adjustments were made to the next journal prompt where indicated by the data.

Each student's journal was private and confidential in order to encourage authentic, honest communication, unfiltered by self-protective fear of disclosure. The journal's use as a research instrument was explicitly communicated to and understood by the students. Additionally, "This is for the NSF data" was printed in the instructions on the page with the weekly prompts. As promised, the students' identities and identifying factors have been disguised.

Prompts were based on a simple theme along the lines of, "what's going on regarding…." For this report, we are using data from journal entries 2, 3, 6, and 9 as seen below.

> At the end of week 2 Date: _____
> Settling into work: Describe your INITIAL observations of the relationships between the people you have met in the lab. (Describe the tone of what appears to be the working relationships between the PKU PIs, grad students, undergrad, & other employees; How did your hosts welcome/introduce you to your PKU colleagues? How long do you predict it will take for you to feel like a "native" in the PKU lab community? Which folks have been most helpful and how? Who do you think is most likely to be your go-to person for support and why?)
>
> At the end of week 3 Date:_____
> Finding your way around: Describe your EARLY observations regarding the lab environment itself. (What's familiar/unfamiliar/interesting re: equipment, spatial layout, technology, methods/materials, accessibility, relationship to the PKU campus, etc.? What are the relationships between the people and the lab equipment/space? What are your early thoughts about your own competency in this lab environment? What's been easiest or most difficult for you so far? Comparisons/contrasts with GT?)
>
> At the end of week 6 Date:_____
> Work: Describe what's going on with your research in the lab now. (Are you achieving what you hoped you would?—explain how or why not? Who in the lab is encouraging or impeding your work? Any "aha" discoveries that have been encouraging? Any disappointments? Any plans/hopes/fears concerning achieving your GT lab's goals in the remaining 5 weeks?)
>
> At the end of week 9 Date:_____
> Reflection: Now that you've been working in the PKU lab for 9 weeks, revisit what you wrote after Weeks 2 & 3 and update your original observations of the lab/technological environment and your participation within it, the relationships between the people in the lab, and the work that you're doing. (What's going on in the lab and with the work NOW?)

Interviews: CURE students were interviewed individually, in sub-groups, and as a whole group during the site visit and after returning to the US. Participants were asked to validate the patterns in the data as they emerged.

Scholarly Participation as evidence: Tracking participants over time will provide one means for observing long-term, lasting effects success of CURE participation. Even though the first CURE cohort has only just completed their year (December 2010), we have begun tracking their engagement in scholarly and academic endeavors (i.e., papers, publications, competitions, graduate school applications, conferences, leadership in professional organizations, etc.) as they relate to research, science, and engineering. This can only be reported in limited form here because of the short time since the first cohort's participation (ending December 2010). Three years of CURE data collection and analysis cycles should provide meaningful evidence and a rich understanding of the effects of the CURE program for promoting graduate school studies, increasing awareness of international aspects to a research career, and undergraduate researchers as a link between international labs. This will be reported in future publications.

Discussion

CURE is designed around three goals. We wanted to provide undergraduate students with an international research experience that had the potential to:

(1) offer a global perspective on research challenges and opportunities in the field of biomedical engineering while enhancing their skills in scholarship and innovation through research;
(2) motivate students not only to enter graduate studies, but also to enroll in a graduate program with an international component;
(3) link the work, communication, and cultures of three institutional partners through the CURE participants as a shared asset.

In this section, we will address what we have begun to learn about achieving each of these goals.

Goal 1: Becoming a Member of the Global Biomedical Engineering Community

For this first CURE cohort, working and living among a cadre of engineering practitioners and students from around the globe allowed the participants to define themselves as global engineers and scientists, to think of themselves as citizens of the larger geographical world, and to visualize their own future in an attainable way. As biomedical engineering researchers they shared a work and practice identity with these other international engineers—some of them students, some of them young professionals. In addition to meeting other engineering students in their international dorm on the PKU campus and its neighboring university campus, they reported meeting and socializing with members of the engineering community in coffee shops, at the World Expo in Shanghai, and in dance clubs, pubs, and restaurants in the evenings. One student described it thus:

> *Besides gaining confidence with finding friends at GT through the group of 8 people I came with, I gained confidence in general by meeting people outside the group. Every person, well foreigner, that I met was very successful…. I also made friends with people from Harvard, Yale, USC, UCLA. People studying from South American, Paris, and*

Australia. It expanded my goals and dreams for when I am done with GT. It raised the calibar for the accomplishments I want to complete once I graduate. I guess you could sort of say it expanded my horizon![1]

The freedom to experience the Chinese culture and landscape through independent travel and movement afforded the CURE students an opportunity to realize the influences of a global economy that is increasingly linked by travel, information, and commerce. Student C described his observations of this phenomenon:

> [In rural China] *I had a beer named Tsingtao, and the bar was playing a song that a friend of mine loves. I texted my friend back in the States about it. The whole thing suddenly seemed very surreal. The beer Tsingtao was originally made by Germans after the Eight-Allied Invasion of China. China gave the city up to Germany as a condition of its surrender. So there I was in a bar in China drinking a beer made by Germans, listening to American music, and texting my friend from thousands of miles away (using a phone made in China, whose microchips were made in Indonesia, and a screen designed in Korea). It made me realize how interconnected everything is now. One of my favorite books is called "The World is Flat," and it was at that moment that the world truly felt flat and so small. No accomplishment, advancement, product, or anything can be claimed by a single country now. Everything humanity does now is a global effort in every sense.*

The CURE students appreciated the universally positive work relationships that they shared with their PKU graduate student mentors but did not develop social relationships with them that extended outside of the lab or their shared work. The mentors made the effort to make their CURE colleague(s) comfortable in the labs by sharing their science expertise and using English as often as possible. They were gracious hosts and teachers. Some of the labs were social during the workday, sharing a meal during office hours—sometimes breakfast, sometimes lunch. There was also an occasional after-hours graduation party to which some CURE students were invited.

> Student W: *People in my lab have been very friendly and helpful. The grad and undergrad students all respect the PI a lot. My hosts bring me to different dining halls every day and show me around PKU on the way to the dining halls.*

Overall, the CURE students formed a bond with their mentors through the shared work and work-space.

> Student H: *I also gained a ton out of getting to know my mentor.....She has taught me skills that I can carry back home at GT and can use for research in the future.*
> Student G: *Last week, I watched my guy, LXP, synthesis some molecular which I don't understand. I got some papers from him to read, so hopefully by the end of the week I can understand more of what he is doing. LXP was a chemistry undergraduate and now works in Professor X's lab, who has a collaboration with my lab back in the states. Little L, what I call him, is super awesome; he tries to speak English all the time to us, teach us*

[1] Data transcriptions used throughout this document are authentically as submitted by the participants without correcting writing conventions or mechanics. Changes are limited to removing identifying factors.

about the stuff he is doing, and is never demanding like my lab guy back home. He also offered to take us around during the weekend.
Student B: *The most helpful person in the lab is my mentor LSS. She helped teach me their technique of making gels and also cell culture by a very hands off approach which made me learn a lot in just a week.*

Goal 2: Inspiring Graduate Studies with an International Element

To fully understand how participation in CURE influences continued graduate study- and specifically graduate study with an international component, we will need to allow time for many of the CURE students' to reach the appropriate matriculation stage for making academic and professional decisions about their futures. However, we can report at this time that two of the nine students have applied for admittance to the Georgia Tech-PKU joint PhD program. One of those students described her first consideration of that decision at the end of the summer in China:

I think through the end of all of this, I will look into the joint GT/PKU PhD program. I never would have believed that the CURE program would offer me so many opportunities for the future….. Through my trip I've seen so many opportunities for BMEs in graduate schools like PKU or Tsing Hua and also in business from speaking with other BMEs working in Shanghai….. I'm going to continue learning Chinese…. I hope to get a minor in Chinese and I know now that I will be able to incorporate it into my BME degree.

While not specifically tied to graduate study, we have some additional evidence of scholarly engagement in two other examples. One student wrote a proposal for a President's Undergraduate Research Award (PURA Grant) and received funding to travel to an international conference with his Georgia Tech lab, he credited CURE with inspiring him to do so. Another student entered a course-developed original device in a campus-wide innovation competition (InVenture Prize) and won second place ($10,000, a patent filing, and professional support to bring the device to market).

Goal 3: Undergraduate Researchers as a Shared Asset

Of the three CURE goals, this first implementation taught us the most about the third goal: undergraduate researchers as a shared asset for linking international institutions and promoting collaboration between the Georgia Tech/Emory BME labs and the PKU partners. We learned that our "student as shared asset" model would need to be adjusted to fit PKU's expectations and experiences. We discovered that the CURE participants' first task would be to begin shifting the PKU culture towards recognizing the value of the undergraduate researcher.

Naively assuming all partners were working with the same understanding of the capabilities of undergraduate researchers, we planned for the students to be put to work at PKU in the same way that they are here and, thus, their hands and skills would provide a connection between the international labs separated by geography. Thus, we anticipated a sort of seamless stream of work that the students would begin here, continue there, and finish upon returning here. However, we discovered that our expectations were not fitted to the PKU experience. In fact, the

first undergraduate students in the PKU BME degree program did not begin their freshman course of study until Fall 2010, the semester following the first CURE summer. Undergraduates have not previously been a part of their milieu.

The 2010 CURE cohort served as a shared asset not as we predicted through the contiguous research, but in another way that is invaluable to establishing and nurturing the international research collaboration that we seek. We now see that the 2010 CURE cohort served as teachers or trainers for the PKU PIs and mentors. We believe that the first CURE cohort laid the foundation for those to follow by demonstrating how undergraduates can be integrated into the work and work space, what undergraduates are capable of doing, how much experience and knowledge they bring to the work. One student described how her work ethic and accomplishment influenced her PI and members of her lab:

> *I had so much confidence during my presentation, I was proud of all my work I accomplished and the results I gained. At the end of the presentation, the entire lab was encouraged to ask me questions. I answered all questions without hesitation even though I only had experience on the subject for 2-3 weeks…. Dr. X called me one of the hardest workers she's ever known, and after my presentation she invited me to talk with her outside. She was proud of all my accomplishments and she told me I would be a wonderful asset to her research team at PKU. She offered more opportunities in research until I graduate and she stressed that she wanted me to join her lab in graduate school, possibly take part in the joint GT/PKU PhD program. Dr. X said she would 'never forget my face' and she wanted to see me again. Her final words were very touching.*

In addition to not sharing the same understanding of what an undergraduate researcher can be expected to do, miscommunication between the partnering PIs prevented the CURE students from continuing the research that they had prepared to do during the first semester of the CURE project in the Georgia Tech/Emory labs. For example, a couple of students discovered that the equipment that they were sent to PKU to learn how to use was out-of-service for the summer while being moved and, thus, their/our plans went out the window as they were assigned to random labs; one student discovered that the substance he needed for his research was not in Peking so his work was delayed for the several weeks that it took to ship the materials from the U.S.; another student was frustrated by a resistant PI who refused to support the research as it had been arranged. In its place the students conducted new (and, in some cases, unrelated) experiments, read numerous journal papers, and edited the English in the papers that their Chinese lab colleagues were writing. By the end of the summer at PKU, each had found a way to contribute and, in some cases, tie their PKU work to research to be continued in the U.S. Their initial disappointment and frustration turned to pride as each contributed something of value to their lab and recognized what they had learned in the process. Their self-confidence grew as they were able to see evidence of how much they had learned about themselves and science/engineering by adapting to the change of plans. For example, one student who had been blocked from the research that she had planned to do summed up her lab experience thus:

> *My proudest moment is my final presentation in front of the entire lab and Dr. X. Even though we had 2 ½ months to work in lab this summer, my research only really began 2-3 weeks ago. Within these 2-3 weeks I completed learning a completely new topic that I don't work with at home, new testing methods I have never used before, and analysis*

methods which were new as well. Even though I was only given a small amount of time on my research, my presentation showed absolutely no sign of not knowing the topic and presented very valid and noteworthy results. My conclusion related what I did here to what I do back at Georgia Tech, which I felt was a good wrap-up for the entire summer research which would make both my lab and Dr. X happy to see…. I was very proud of myself, and I know that others were as well.

Overall, the PKU lab personnel were positive and receptive about hosting an American student and expressed an eagerness to send their own students to the U.S. In most cases, there was an assumption, on the PKU side, that the CURE student's main goal should be to explore China while doing a little work around the lab. They were not prepared for the ambitious work ethic expected of and exhibited by the CURE student. This created a disturbing dissonance for the CURE students who had the opposite expectations: work first, play second. It also created a learning opportunity for the PKU PIs and mentors as they observed the CURE students' commitment to the work and preparation for research.

Student M: *When I first started working in lab, I had a very busy lab schedule. I would usually go into lab Monday through Friday from 10AM to about 3 or 4PM and on Sundays at 9AM for the weekly lab meeting. However, the work in lab has now slowed down, and my mentors are now telling me that they will notify me when something is going on in lab and when I need to show up. Some of the slow down has been due to cells getting contaminated, which has caused two full weeks of delays, possibly a third, and the rest of the slow down can be attributed to people in my lab graduating and finishing end of the semester reports, projects, etc.*

I had hoped by this point in the summer I would have been immersed in a research project. At the lab at Tech, I always had a clear goal for my research and could predict where my work would bring me in the coming weeks. At the lab at PKU, I feel that my work has no definite direction and have a hard time seeing the long-term outcome of my work. Perhaps some of my lack of direction comes from the nature and timeframe of the project that I am currently working on. At PKU, my research focus is on biomaterials for cartilage regeneration; whereas, at Tech my research focus is mainly on micro-CT imaging. I believe that the mismatch of research projects is a major factor in my lack of direction. Furthermore, I entered my current research project at PKU near its conclusion and do not have the experience and knowledge that comes with working on a project from the start.

I feel that the lab at PKU is not necessarily impeding my work but at the same time is not encouraging my work either. I have asked my mentor and my professor a number of times during slow weeks if there is anything that I can do in lab. Both respond that there is nothing that I can do and recommend that I explore Peking. I wish that I could be given a task during slow weeks, even if it involves cleaning Petri dishes, just so that I can feel like I am being productive. If there are future delays and slow periods on the project that I am working on, I plan to shadow one of my fellow group members in lab.

Over the next five weeks in lab, I hope to continue learning about biomaterials for cartilage regeneration and gain experience with editing and revising scientific journal articles. Although I have not had as much time in a "wet lab" at PKU as I anticipated, I

have had the opportunity to edit and revise my mentor's paper that he wants to publish. I have been able to apply the knowledge and skills that I learned through both classes and lab at Tech.

Later this student reflected:

The CURE program compelled me to learn a lot of information on topics that I previously knew little about (osteoarthritis and biomaterials). Had I done regular undergrad research, I probably would have only worked on one topic.

The CURE students embraced whatever they were asked to do and took advantage of as much work as was offered, whatever it was. They found various ways to be useful. One student found that editing papers in English was a way to contribute to his lab that made him a valuable asset. One student perfected his Western Blot technique and developed some results that excited his PI. Another student traveled with members of her lab to a remote hospital for five days of gathering data on rural children. While they might not have been working in the area that they would have preferred or as planned, they learned much about themselves as scientists, about labs in other environments, about flexibility and about their personal capacity for "making lemonade out of lemons" as they learned unanticipated lessons from the work that they were assigned. Student C described the experience like this:

As far as professional accomplishments [at PKU], in the end, my compound I was sent here to work with wasn't a success. However, it inspired me to make a new one that's based on Chinese herbal medicine. I think it's a clever idea, and I'm interested in seeing if I can synthesize it when I return to the States. If I can, I think it's an exciting and very promising concept. Plus, it'd be a cool fusion of traditional Chinese medicine and cutting-edge Western medicine. It kind of goes back to the concept that everything we do now is a global effort.

Student S: *I also learned some things about myself as a scientist. I learned that even with inferior equipment, all it takes is a little ingenuity, and luck, to overcome obstacles. Many times I questioned if what I was doing would yield reliable results due to contamination, but I managed to improvise some procedures attempting sterile technique I learned at Emory with what was available in the Chinese lab while combining with the techniques they were used to [here]*.

Student H: *It is weird because I am able to read research papers, related to drug delivery, and actually understand it. This is what made me realize how much I have learned over the course of this past summer.*

Language differences were a struggle but did not pose a barrier to the collaboration for either side. It was not easy, but it was not impossible either. Most weekly lab meetings were conducted in English out of deference to the American guests. Language issues were an inconvenience for both groups but, since most papers are written in English and many of the mentors plan to come to the US for study, the Chinese mentors welcomed this opportunity to practice their English language skills.

Student D: *I work with two grad students who are really nice, but their English isn't the best, so it's a little confusing at times when they're explaining what I need to be doing. I*

think that I will still need a couple more weeks before I'll feel completely comfortable in the lab, as a lot of the lab doesn't really speak English. My grad students will definitely who I would go to for help, especially since they know the most English.

Additionally the language issue limited the students' independence in the lab. The lab is a place set up for the convenience of the full-time residents: Chinese-speakers. Supplies, storage areas, materials are labeled in Mandarin; reading was problem for six of the CURE students.

Student D: ..... *and I am just as confused in lab with the all Chinese labels and protocols.*

Student S on the final week at PKU: *At last, I have learned the secrets of the elusive supplies in my lab and can find things without difficulty. This comes too late as I have finished the experiments I had talked over with my professor.*

Early in the adjustment to the labs, even the Chinese-fluent CURE students reported a language barrier that was sufficient enough to make them feel as though they would "never feel like full members of this lab".

Student C: *Becoming a "native" is essentially impossible, due to my lack of fluency in Chinese. It erects an unavoidable wall that separates me from the group on a certain level. Regardless, I've really enjoyed working with my grad student. He's a great guy and definitely my go-to person*.

Student S two weeks after arrival: *I don't think I will ever be a native in the lab because they don't typically use English to communicate, even when they have presentations. The words up on the big screen will all be English but they will still all be talking in Mandarin. This presents a great opportunity for me to learn the language, but this short time frame is not enough to learn technical and colloquial Chinese. The two grad students that have helped the most are MS and LTF. They both speak some English, and they both will be coming to America shortly after I get back to do postdoc at [other American universities]*.

However, by the end of the semester, there was a subtle shift toward feeling more competent in the lab as the CURE students' mastery of Chinese—technical terms and conversation—improved and as they found their way around the lab space without requiring guidance.

Student S at the end of the semester: *I am learning some technical Chinese though, which I suppose is worthwhile even though all the Chinese labs use English for technical terms nowadays because all the good journals are printed in English….. I'm mostly able to communicate with my lab now, though it still takes a few tries with different synonyms. At last, I have learned the secrets of the elusive supplies in my lab and can find things without difficulty*.

Conclusions

In the first implementation of CURE, we are beginning to see evidence that the program can achieve its goals of inspiring undergraduate students to consider graduate studies with an international component, to see themselves as members of a global community of biomedical engineers, and to serve as a shared asset between collaborating institutions on opposites sides of the world. Although some of the original goals of CURE may not have been enacted in the lab precisely as designed, the CURE experience was a success for all of the participants-- both in personal and professional development. While most students were unable to conduct the research in China as they had prepared during the first semester of CURE (Spring 2010) in their

Georgia Tech Tech/Emory labs, they did make meaningful research contributions and learn how to build collaborative relationships with colleagues from another culture, just as our international partners learned much the same thing from the CURE students.

There was a breakdown in the planned 12-months of contiguous research between collaborating international labs due to miscommunication between PIs and cultural differences in understanding of the capabilities of undergraduate researchers. In the next iteration, we will try some interventions, perhaps in the form of matching mentors on both sides of the collaboration, to see if we can better support the concept of contiguous work. In addition to gaining new skills and confidence that have made the CURE students valuable members of the research community, their work ethic, preparation, and commitment impressed members of the PKU lab communities and laid the foundation for better communication between institutions as we go forward with CURE 2011.

For the next round of analysis, we will look at the full 12-month experience for the CURE 2010 cohort. We will widen our focus to look at the overall program, including the integration of the international CURE component described here. As we gather data from the 2011 cohort, we will begin to overlay their experiences with those of the 2010 cohort to form a more complete understanding of CURE's benefits to undergraduate researchers and to international institutions engaged in collaborative research.

Acknowledgments
This research was supported by the National Science Foundation (Award Number OISE-0927555). The views expressed are those of the authors.

References

Fasse, B. B. (1993) "No Guarantees": An ethnography of transition to parenthood in normative lifespan development. Dissertation: Georgia State University, Atlanta, GA.

Geertz, C. (1983). Thick description: Toward an interpretive theory of culture. In R.M. Emerson (Ed.), Contemporary field research (pp. 37-59). USA: Waveland Press.

Glaser, B.G. & Strauss, A.L. (1967). The discovery of grounded theory: Strategies for qualitative research. Chicago: Aldine Publishing Company.

Goetz, J.P. & LeCompte, M.D. (1984). Ethnography and qualitative design in educational research. Orlando, FL: Academic Press.

Lincoln, Y.S. & Guba, E.G. (1985). Naturalistic inquiry. CA: Sage.

Measor, L. (1985). Interviewing: A strategy in qualitative research. In R.G. Burgess (Ed.), Strategies of educational research (pp. 55-77). Philadelphia, PA: Falmer Press, Taylor & Francis.

Merriam, S.B. (1988). Case study research in education: A qualitative approach. CA: Jossey-Bass.

Schacter, D. L. (1999). The seven sins of memory: Insights from psychology and cognitive neuroscience. American Psychology, 54, 182-203.

Spradley, J.P. (1980). Participant observation. NY: Holt, Rinehart & Winston.

Stake, R. E. (2006). Multiple case study analysis. New York: Guilford Press.

Yin, R. K. (1984). Case study research: Design and methods. CA: Sage.