

Cyberinfrastructure Internship and its application to e-Science

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Abstract – Universities are constantly searching for ways that prepare students as effective global professionals. At the same time, cyberinfrastructure leverages computing, information, and communication technology to perform research, often in an international context. In this paper we discuss a novel model, called the Cyberinfrastructure Internship Program (CIP), which serves both of these goals. Specifically, students apply or develop cyberinfrastructure to solve challenging research problems, but they do this via summer internships abroad. CIP has been implemented at three different Universities: The University of California San Diego in the US, Osaka University in Japan and and Monash University in Australia. We discuss details of the schemes and provide some initial evaluations of their success.

I. INTRODUCTION

Recently there has strong interest by universities, and the education community in general, in international activities [39][11][13][14][18][16]. There are many drivers for this. Globalization, for example, demands an internationally competent workforce, and access to good jobs will require new skills and competencies, especially global knowledge and skills [29]. Solving large-scale problems such as environmental and natural disasters, requires increased knowledge of other world regions, histories, cultures and languages, in combination with advanced computing technologies. Likewise, increased diversity in classrooms, workplaces, and communities, including new immigrants and international students, requires, greater understanding of multiple cultures and histories. At both the University of California at San Diego (UCSD) and Monash University, around 25% of the undergraduate students are from overseas. Moreover, at UCSD 43% of the students speak a language in addition to English (and of those more than 50% speak a language from the Asia Pacific Rim) [43].

Increasingly, governments are recognizing the importance of the role advanced computational infrastructure to support research and development. In the UK, the e-Science program was created to address the shortfall in computing infrastructure, and to apply it to large-scale research projects from a range of disciplines. In the United States (US), the National Science Foundation (NSF) Blue Ribbon Panel on Cyberinfrastructure [10] stated “a new age has dawned in scientific and engineering research, ... [where advances in technology] make possible a comprehensive ‘cyberinfrastructure’ on which to build new types of

scientific and engineering knowledge environments and organizations, and to pursue research in new ways and with increased efficacy.” In addition, to have this cyberinfrastructure interoperate internationally, there is a “need for a new workforce – a new flavor of mixed science and technology professional –... who are trained to understand and address ... working across disciplines, cultures, and institutions using technology-mediated collaborative tools.” The recent report “2020 Vision” by the National Science Board [30] emphasized three strategic investments for the NSF: infrastructure, in particular cyberinfrastructure; a world-class workforce, and a *global* frontier of fundamental and transformative research, emphasizing areas of greatest scientific opportunity and potential benefit. In Australia, the federal government has made substantial investments in e-Research infrastructure through a number of funding initiatives, addressing needs in high performance computing, data storage and collaboration tools [34].

As a result of these two challenges, namely to produce graduates who both understand how to apply and develop cyberinfrastructure, but who are also knowledgeable of global work principles and practices, we have created student exchange schemes at each of our Universities: PRIME at the UCSD in the US; MURPA at Monash University in Australia; and PRIUS at Osaka University in Japan. All three provide opportunities for students to learn and apply cyberinfrastructure during internships abroad, providing them both a technical and a cultural learning experience.

In this paper we discuss a general framework called the Cyberinfrastructure Internship Program (CIP), and show how this is implemented in each of PRIME, MURPA and PRIUS. We then give some examples of successful CIP projects, and perform an initial assessment of the success of the framework.

II. THE CIP MODEL

The CIP model promotes immersive, hands-on international educational advancement and research internship program for science and engineering students. CIP differs from traditional education abroad programs because it allows students to participate in research, working side-by-side with the researchers at the international host sites. In contrast, traditional education abroad programs often involve students in traditional lecture style courses, and do not involve research projects, internship or mentoring.

In general, CIP's focus on two orthogonal themes: *research apprenticeship* and *cultural competency*. These components, the logistics, inputs, outputs and outcomes are shown in Figure 1. 'Inputs' to the scheme typically involve a series of steps that begin before departure, continue through the internship and finish after return. Inputs are clustered around research apprenticeship and cultural competency. There are also specific 'outcomes' and 'outputs' from the program. Students gain a research experience, and in many cases, new collaborations between mentors are created. Students may publish their work in peer-reviewed conferences and journals, and in some cases produce software tools and systems. The program aids research at the host sites, and helps produce a globally aware workforce, that is not only technically savvy, but also culturally aware.

In CIP, there are three key contributors to and beneficiaries of the outputs and outcomes: the students, the home university mentors, and the host mentors, and later we will analyze the scheme from these perspectives. Here we discuss the research apprenticeship and cultural competency components in a little more detail.

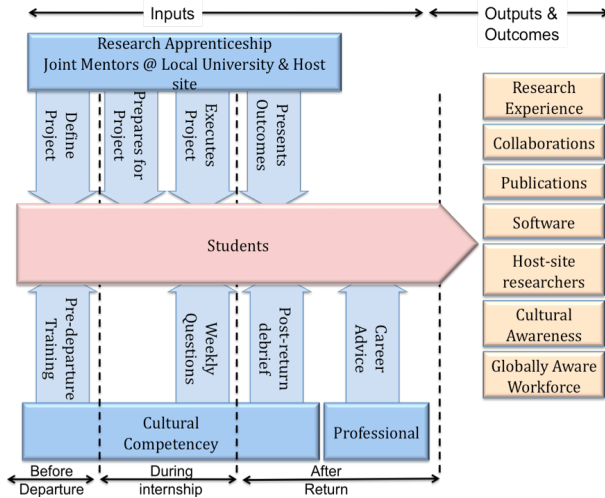


Figure 1 – CIP and its components

A. Research Apprenticeship

Research is a process that includes the identification, formulation and contextualization of a research question, and the determination of the methods and tools most likely suitable for solving the research question. CIP makes students aware of this by involving them in all of those steps. Students must initiate contact with a local university mentor as well as a host site mentor to discuss research possibilities, and to develop a project proposal. Students who have been selected prepare for the internship before leaving. Under the guidance of both mentors, students acquire the necessary background knowledge of the research topic and, if applicable, acquire the skills to use the cyberinfrastructure tools. At the host site, students are then immersed in a research team for around nine weeks (a typical 'summer' break). This provides them with sufficient time to make reasonable progress on a research topic of some scale. Later in the paper we produce some examples of the research projects that have been undertaken.

The internship culminates in a presentation by the students at their host site (often virtually using video

conference systems) with their home institution, emphasizing the value and need for communicating their results to a broader audience. In addition, upon their return, students often present their research at a workshop

B. Cultural Competency Learning

In CIP, students are exposed to some level of cultural competency training, in particular, aligned with four stages of cultural awareness [31]:

- blissful ignorance of cultural difference and behavior (unconscious incompetence);
- realization of difference but little knowledge of how to behave (conscious incompetence);
- realization of the difference and with effort knowledgeable about action (conscious competence) and cultural awareness; and
- action as second nature (unconscious competence).

Recognizing that students have different levels of awareness of the host culture, CIP tries to move students towards "unconscious competence". We use this model to raise awareness of cultural differences, and to begin changing students' attitudes and behaviors.

Pre-departure cultural competency training, begins with a definition of culture, and explores verbal and non-verbal behaviors that reveal cultural attitudes and values. While abroad, students reflect about their experiences in their new environments by answering weekly questions. Upon return to their home institution, students engage in a series of face-to-face "re-entry" meetings to consolidate their cultural experiences.

III. CIP IMPLEMENTATIONS

We have implemented the CIP model in our home universities, building it into the native pedagogical structure of the institutions. Whilst each of PRIME, MURPA and PRIUS share the same CIP framework, they differ in the emphasis placed on specific aspects of the model. All three CIP schemes leverage an existing collaborative platform called PRAGMA, the Pacific Rim Application and Grid Middleware Assembly, for the participating international partner (host) sites and many scientific and technological development projects. PRAGMA, established by an US NSF award in 2002, provides the technical and human network for the students. Since inception PRAGMA has grown to more than 30 institutions around the Pacific Rim, with both application scientists and technology developers working collaboratively to make cyberinfrastructure usable on a routine basis [3][8][44]. Here we discuss some of the unique differences of each of the schemes.

A. PRIME

PRIME was started in 2004, with support from the US National Science Foundation and California Institute of Telecommunications and Information Technology (Calit2) as well as a number of partner institutions, as a pilot activity to prepare students for the global workforce of the 21st Century. PRIME builds on the strength of four key units or research organizations on the UCSD campus. Because it has run the longest, PRIME is the most mature of our CIP implementations, as will be evident in this paper.

To ensure that students are academically prepared, and that they are mature enough to deal with the

challenges of living and working in a foreign country, they must have a grade point average of at least 3.0 out of 4.0, and must have earned credit equivalent to completing their first two college years. Students must also return to UCSD for at least one quarter.

Of the three programs, PRIME has the most developed and formal cultural competency component. Before departure, students engage in a two-hour workshop in which they analyze several critical incidents and ask “what happened?” and “why?”. This encourages them to use cross-cultural thinking and vocabulary that describes the incidents. Different types of communication are discussed, such as direct/indirect, with and without eye contact, and physical proximity, demonstrating each to illustrate the points. The addition of cross-cultural incidents and ways to analyze them is considered an integral and important part of the “learning how to learn” process, including how to recognize, characterize and respond to meaningful cultural differences. The sessions’ format is a full group activity, followed by discussion and activity in small groups. Finally, perspectives are shared with all participants. Subsequent to the workshop, new participants interact with prior years’ students to better understand possible cultural and logistical challenges that await them.

Whilst away, students complete training material based on “What’s Up With Culture” [32]. Students learn to discern knowledge about cultural differences and similarities without assigning values, i.e., better or worse, right or wrong, to those cultural differences. The materials are based upon ‘cultural-general’ models and theories of intercultural communication that are applicable across a wide range of human societies, and are illustrated with global examples of communication mistakes. Especially useful are cultural ‘contrast’ sets that allow students to place general cultural patterns into non-stereotypical categories on a continuum (e.g. ‘individualist’ societies vs. ‘collectivist’ societies or a preference for “direct vs. indirect communication” styles). These types of models can then be supplemented by “culture specific” material appropriate to country and setting. Using a general framework makes it easier to understand macro cultural patterns and allows subsequent micro ‘culture specific’ knowledge to be placed into a broader context.

Upon return UCSD, these online contributions are enhanced in a face-to-face “re-entry” meeting using exercises that explore issues such as concept of time, gender roles, professional hierarchy, communication styles, international lab procedures and techniques, different thought processes and approaches to scientific questions and social interactions with peers in the host country. Through this, PRIME participants learn to appreciate (rather than judge) that different cultures have developed their own specific ways of carrying out or expressing behavioral patterns that are shared by all of humankind collectively.

Students are encouraged to use their new awareness to begin understanding the cross-cultural situations they encounter in their everyday lives, and use this knowledge to work more effectively and harmoniously with colleagues of backgrounds different than their own.

B. PRIUS

The Pacific Rim International Universities (PRIUS), [12] [21] was created in 2005 and was funded by the Japanese government. PRIUS provides a broad intellectual framework at the graduate level, combining:

- Lecture courses, taught by international experts, to stimulate student interest (many of who are PRAGMA members). During 2008 alone, more than 20 experts came to Osaka University, generating a great deal of interest in the other components of the program.
- Short internships abroad, to offer trial opportunities to live in a new environment
- Long internships abroad and to provide opportunities to build skills

PRIUS’s goal is to prepare graduate students for global citizenship and professional competence in a multi-cultural workplace through international immersive research experiences/internships.

PRIUS students have also performed research at UCSD, other PRAGMA partner sites in Australia (Queensland University of Technology), Singapore (National Technological University), Taiwan (NCHC), and Malaysia (Universiti Sains Malaysia), and at additional sites in the United Kingdom (University of Oxford), Germany (Bauhaus University), and New Zealand (University of Canterbury). The extension of PRIUS to these additional sites has demonstrated the flexibility of the CIP model to a broader, world-wide set of institutions. In addition, they too have published papers [42][37][36][38], and have had direct impact on improvement or extension of middleware used by the community. In 2007 the success of PRIUS partly contributed to Osaka University’s participating in Japan’s Global Centers of Excellence program (MEXT). MEXT will establish education and research centers, to elevate the international competitiveness of the Japanese Universities.

Like PRIME, PRIUS invests in cultural training; in fact, this aspect is one of the main drivers for PRIUS since Japanese students are rarely exposed to competing cultures throughout their degrees. PRIUS does not make as much use of the formal instruments (such as the IDI [33]), however, students engage in similar pre and post visit training and debriefing.

C. MURPA

In 2007 Monash University developed a similar program to PRIME, and received internal seed funding to create MURPA (Monash Undergraduate Research Projects Abroad) [26]. MURPA delivers a PRIME experience for Monash undergraduates, and inherits all of these benefits discussed in this paper. MURPA students undertake an 8 week program across the southern hemisphere summer.

The first MURPA intake occurred in Jan 2009; over the three years 12 students have been sent to UCSD, and 2 students to the NCSA at the University of Illinois, Urbana Champaign. The main goal of MURPA is to promote a teaching-research nexus in which research is integrated into traditional under-graduate education. The benefits of this include producing graduates with enhanced research skills that can be applied on top of their formal education. Such skills are highly valued by

employers and produce better-rounded graduates in general. MURPA internships are actually performed after students have completed their basic three year degrees, and thus they are fully qualified as practicing professionals. However, a condition of MURPA is that students return for an additional fourth year, called Honours in the Australian system. The Honours degree allows graduates to deepen their knowledge of certain topics, as well as enhance their research skills through a major project. As such, MURPA provides both an incentive and further training for the Honours year. In about half of the cases, students have chosen to extend their MURPA project into their Honours research project, and have kept engaged with their international mentors during the entire year. Like PRIME and PRIUS, some MURPA projects have produced publications [4][40].

Different from PRIME and PRIUS, however, MURPA allows Monash students to attend 'virtual' seminars given by leading experts from the host site. These use the latest High Definition Video-Tele Conference equipment (HDVTC). Six seminars were delivered from the CallIT2 building at UCSD in 2008, and were hosted in the Faculty of IT video conference facilities in Australia. In 2009 and 2010 this was extended to a complete semester seminar program, and integrated the seminars into the Computer Science curriculum at Monash University. These seminars are an important aid for students to locate suitable remote mentors because they can attend a seminar on topics of interest to the mentor, and use this in helping to synthesise a project. Unlike PRIUS, which uses face-to-face seminars, MURPA can deliver an equivalent experience at a much lower cost (and more environmentally friendly). We also used this technology to allow MURPA students to present from UCSD their final presentation to faculty at Monash University.

Unlike PRIME and PRIUS, the cultural competency components of MURPA are currently less formal, and whilst pre and post internship sessions are held, they do not rely on formal programs and instruments. This is likely to change as MURPA matures and as a wider range of target countries are added (In 2012 we plan to send students to Israel, for example).

IV. CIP SAMPLE PROJECTS

Because PRIME, MURPA and PRIUS leverage the PRAGMA initiative, all projects either apply or develop cyberinfrastructure. The projects are defined both by the interests of the students and mentors. As such, some projects build on results of prior projects [20], whilst others bring in new areas and researchers [5]. The interests of the host mentors are diverse and include drug discovery, image processing, cardiac modeling, molecular simulation, sensor networks, scientific visualization facilities (typically tiled display walls) and earthquake engineering.

CIP research projects exploit unique attributes of the (remote) host site and therefore would not have been possible if done solely in the host country. Specific examples include learning from the authors of a key middleware, such as Nimrod that was developed at Monash University [27]; using data from the host site, such as Malaysian natural compounds available at the

Universiti Sain Malaysia; studying earthquake engineering at a world center such as at the National Center for Earthquake Engineering in Taipei; or studying aspects of a specific lake or coral reef on site, such as at University of Waikato. Importantly, none of these opportunities would be available if the host site was not at another university or research institution. Admittedly, choosing another university in the same country might deliver a similar variety of areas, but the benefits of studying and working abroad are significant. CIP highlights the benefits of choosing host sites from other PRAGMA members. In all cases students are immersed in the research hierarchy and sociology at the local site, which can help them in future interactions with scientists from that culture.

Projects require students to learn new technologies which are either conveyed to their host institutions (e.g. display technology made from regular flat paneled screens that have been arrayed into a larger one, with the appropriate software to allow the collection of screens to act as one, i.e. tiled display wall technology) or brought back to their host mentor's lab (such as the use of specific software). We give some examples of recent projects:

1. Students used the Nimrod cyberinfrastructure tools [2] (developed at Monash University in Australia) in the development of cardiac models (developed at the Cardiac Mechanics Research Group at UCSD). Projects have worked on a variety of problems from improving the accuracy of ionic models through to full electro-physiological simulations of the heart. We have supported both PRIME and MURPA projects, and in some cases have had students hand the project over to a following intern. In this way, some projects have benefited from two internships per academic year, and have been split between MURPA and PRIME. In 2010 a MURPA student continued his project as part of his Honours year, as discussed in section III.C.
2. A team of PRIME students worked on a study of the avian influenza virus, subtype H5N1, screening neuraminidase and hemagglutinin proteins, respectively, against two libraries of compounds. They have applied AutoDock [15] and DOCK [17], software tools designed to predict how small molecule drug candidates bind to a receptor of known 3D structure, to screen the NCI diversity library representative set of 2,000 compounds, and 1,000,000 ZINC library compounds [35]. Students identified certain receptor residues that were especially important to ligand binding and future drug design. Again, this problem domain has supported internships across multiple years, and has occurred at more than one PRAGMA host institution. In one year, for examples, two students were sent to different host sites but had similar projects. They used video conference technology to allow them to interact between Melbourne, Australia and Osaka, Japan during their internships.
3. Another PRIME student used image analysis as a computational tool in identifying functional biological neural networks. These networks provide the framework for constructing three dimensional representations of the dynamics of cells. She

successfully determined the number of cells present in a still image taken from a movie of astrocytes, the largest and most proliferate of glial cells in the central nervous system.

4. A number of PRIME and MURPA students have worked on visualization projects using tiled display walls and 3D caves. They employed COVISE [24], the COLlaborative VISualization and Simulation Environment, and added features to make it more usable. This area has also supported tag-teams of PRIME and MURPA students on a continuing project, in this case, adding 3D immersive visualization features to an astro-physics simulation. Because COVISE supports multiple devices, it was possible to leverage different hardware available at UCSD and Monash.
5. A PRIUS graduate student worked on the development of multi-site virtual cluster at UCSD in 2010. The project aimed to integrate an overlay networking technology into the Rocks technology, a cluster installation and management tool developed at UCSD so that the Rocks allows people to build their own virtual cluster composed of multiple virtual machines, each of which may be located on different institutions.

Importantly, a number of these projects have resulted in publications in peer reviewed conferences [41][1][5][6][4][40] or software such as Cytoscape [22]. All of them have generated outcomes of interest to the mentors, and have underpinned further research and collaborations. Importantly, the projects leverage the international flavor of PRAGMA, and provide opportunities that are not available in any one country as noted at the beginning of this section. In some cases this is because the software environment and expertise at the remote site is unique. In others, it is because the local culture is a key component in the research. Finally, exposure to the local culture (and language in many cases) is a critical component of the research experience.

V. CIP ASSESSMENT

As outlined in Figure 1, CIP has a number of tangible outputs and outcomes, namely: research experience, collaborations, publications, software, host-site researchers, cultural awareness and a globally aware workforce. Clearly, our implementations of CIP have not been operating long enough to perform a full longitudinal study and assess the performance of the scheme against these outcomes. Each of the three CIP programs have operated for differing amounts of time, so the assessment does not focus uniformly on any one scheme, and the results need to be taken only as early evidence of success. We address each of the outputs in turn and evaluate the performance of that output against a range of performance metrics. These assessments allow us to monitor student growth, improve the CIP program, and build connections to promote research and scholarly collaborations.

A. Research Experience

Recently, we examined the qualitative impact of CIP on participants with small focus groups of students. In assessing research experience, three PRIME students

from the first 2 years of that program are currently pursuing higher degrees (MD/Ph.D, CS Ph.D, Computational Chemistry Ph.D) and one works in industry. All of the 14 MURPA students have proceeded to the Honours year, which as discussed is specifically designed to hone their research skills (admittedly this is a requirement for financial support). Further, one MURPA student has since started a Ph.D. All graduates acknowledged PRIME's influence on their use of computing, its immersive experience working at an international lab and the effect on their thinking, and often their career path (one is now studying abroad). Also, several mentioned the opportunity to work on projects with different cultures was important to their profession, and how the experience helped them develop independent problem solving abilities.

B. Generation of new collaborations

Long-term research collaborations have been enabled by all three implementations of CIP. In Table 1 we give some examples, indicating the specific collaborations. There are several explanations for these ongoing collaborations, ranging from the interests and dispositions of the specific mentors and the host mentors, clearly defined projects, and building upon the works of previous students and other activities. The table shows pairs of laboratories, identified by short identifiers. The meanings of these are shown in Appendix A.

C. Publications

As shown in Table 1, there have been a number of publications produced directly from the CIP programs.

D. Software and new products

Several software components have been developed and distributed as shown in Table 2.

Other outcomes include new products or services. For example, the Global Lake Ecological Observatory Network (GLEON) [23] is a grass roots network of limnologists, ecologists, information technology experts, and engineers who have a common goal of building a scalable, persistent network of lake ecology observatories. Currently there are more than 290 individual members and more than 30 sites around the world interested in sharing data. A PRIME student developed a controlled vocabulary for data from sensors from two lakes, one in New Zealand and on in Wisconsin. In this case, key words and phrases were developed that can be shared among lake scientist for comparing measurements. This list has been adopted by the Global Lake Ecological Observatory Network (GLEON) and will be a basis for being able to share data.

Table 1 – CIP Outcome Statistics, 2004 – 2011

Host site 1 Site:Lab	Host site 2 Site:Lab	# Yrs of Shared Studs	# Students Shared	# Shared Pubs
UCSD: CMRG	Monash:MeSsAGELab	8	20	4
UCSD: VBL	Osaka: AISIELab	7	14	6
UCSD: NBCR	CNIC Monash:MeSsAGELab	6	13	4
UCSD: Vis	Osaka: AISIELab NCHC	5	13	2

	Monash:MeSsAGELab			
UCSD: CompChem	Monash:MeSsAGELab	6	9	2

Table 2 – Software Components developed by CIP students

Software Developed	Context
Hyperbolic Focus Layout Plugin	Cytoscape Plugin, that allows viewers to see relationships via a hyperbolic focus, bringing into focus relationships of greater interest.
Thumbnail Browser	A file browser plugin for Covise, for ultra-high resolution images, which can run on a tiled display wall or in the Starcave at Calit2
Enhancements to Image Viewer	A plug in to Covise, with added functionality to allow for the viewer to lay out a number of image files on a grid so that multiple images can be compared side by side on a tiled display wall.
Diffusion Tensor Imager	A plugin for the CONTINUITY software for visualizing diffusion tensor images from MRI.

E. Host site researchers

There are several qualitative benefits for host sites, namely that the programs: expose staff to work in an international context; improve the depth and quality of local research; and internationalize the host institution. In addition, there are tangible benefits in terms of collaborations over several years and publications (Table 1). Further, the MURPA and PRIUS programs were spin offs from PRIME, demonstrating value to host sites. Finally, staff exchanges have occurred, for example between Monash University, Osaka, CNIC and UCSD. These all indicate benefits for host site researchers.

F. Cultural awareness

To assess the impact of the cultural experience, we use the “What’s Up with Culture” and four stages of cultural awareness model from La Brack, as well as the Intercultural Development Inventory of Bennett and Hammer. To date, PRIME is the only CIP site to use a formal instrument, and thus the conclusions here are limited to PRIME. However, we have anecdotal evidence of cultural shift at the other CIP sites.

The What’s Up with Culture website contains questions of 75 long-term impacts during our first year. Subsequently we asked the students to respond to weekly questions during their time at the host site (see Weekly Questions [19] – also based on questions in What’s Up with Culture [33]. A summary of the responses has been compiled for the years 2 through 4 (2005 - 2007).

Although we do not expect the students to attain “conscious competence” given the limited length of the summer immersion, we believe that both “conscious incompetence” and “conscious competence” represent significant progress towards attaining the ability function in a new environment.

In addition to students’ stage of cultural awareness, we employed a more detailed assessment instrument (IDI) that directly measures their attitudes towards difference. As part of the preparation for the orientation every student takes the Intercultural Development Inventory (IDI). The twenty one PRIME 2008 student cohort took the IDI pre and post departure [33]. Evaluation of the pre departure group indicated

minimization, which is the tendency to minimize difference between cultures. This is a common finding among groups of university students preparing for a study or internship abroad experience. After nine weeks abroad, the students were re-evaluated. The results showed that the students remained in *minimization*, albeit with a slight though statistically insignificant shift from 2.49 to 2.42. This movement is not large enough to indicate a shift towards ethnocentrism. However, they did experience an increase towards *reversal*, from 3.57 to 3.17, which is the tendency to be more critical of their own culture. Another important finding was that students advanced in the *acceptance/adaptation* range from 3.12 to 3.44. Bennett and Hammer found that people taking the IDI “...develop their sensitivity on each of the stages simultaneously. That is they do not have to completely resolve the issues involved in one stage e.g. *reversal*) before moving on to the next stage e.g. *minimization*)” [7]. So it is completely consistent for the group to remain in *minimization* while developing greater *adaptation* after their experience.

The 2008 cohort took the IDI again one year after their experience abroad ended. Students remained in *minimization*, declining slightly to 2.33. However students become less critical of their own culture, as demonstrated by the *reversal* scale increasing to 3.62, which is slightly higher than before they went abroad. Also, the group’s continued advance in *acceptance/adaptation* to 3.61. The 2009 cohort also took the IDI pre and post PRIME. The group advanced slightly in *minimization* from 2.34 to 2.59. The group became slightly more critical of US culture, which is demonstrated by the *reversal* data, which declined from 3.58 to 3.35. The group remained unchanged in *acceptance/adaptation* at 3.80.

Several additional years of data will need to be collected before we can draw more definitive conclusions, but we are encouraged by the early signs that students are beginning a life long process of learning about and adjusting to other cultures.

G. Globally aware workforce

It is not possible to provide quantitative assessment of this criterion so early in the program, and evidence will only emerge after many years of operation. As outlined before, we created CIP to prepare students to become effective members of the global workforce. We know that leading high technology companies increasingly value international experience when recruiting and hiring new college graduates. For example, Google makes hiring decisions based on whether an applicant has worked or studied abroad because they require diverse, multi-lingual, inter-culturally competent workers who can function effectively on international work groups and with international clients [25]. Graduate engineers must understand a multiplicity of cultural approaches to engineering design because they work as system integrators on fast changing international functional teams. CIP’s cultural competency program has been created to develop and hone these soft (non-technical) skills.

VI. CONCLUSIONS & FURTHER WORK

In this paper we have discussed a general framework aimed at producing graduates that have skills in applying cyberinfrastructure to real world problems, using an international research internship. We illustrated three different implementations of this model, and showed that each tends to focus on slightly different features of the general framework. Our initial evaluation of CIP suggests that it is meeting its goals, although a longer term study is clearly required. A more significant discussion and evaluation of the constituent schemes, PRIME, MURPA and PRIUS is available in [9].

Two significant challenges exist for the CIP model: sustainability and scalability. Sustainability concerns the issue of funding continued funding. PRIME is currently mostly supported by a US NSF project. MURPA has internal seed funding from Monash University, and PRIUS was funded on a Japanese government program, but no longer has support. Whilst most people agree that the benefits of CIP type programs are significant, we have yet to establish a viable long term funding model. However, there is reason for hope – each of our home universities have “abroad” type offerings that are self-funding, and we are hopeful that a mix of government, university, student funding and philanthropic donations will provide a viable future for CIP.

Scalability concerns the ability to increase the number of students and host sites. We have already scaled PRIME to more than 10 host sites, and could probably not add too many more without a significant increase in administrative support. Likewise, PRIME currently sends about 20 students abroad each year, and increasing this requires a commensurate increase in funding. MURPA has expanded to two sites in the US, and will send students to Israel in 2012. When we manage to solve the sustainability issues, we could almost certainly increase the number of students engaged each year. However, we don’t envisage expanding CIP to include anything close to the total student cohort. Not all students have an interest in research, nor to all students want an international experience. Further, as the amount of self-funding increases to meet the budget shortfall, students will self select and this will lower engagement. Finally, we only take the best students – providing yet another self throttle. In short, CIP will remain an exclusive cohort.

We have seen significant advantages in CIP and a lot of enthusiasm. There is little doubt that we will see our CIP graduates making substantial contributions to the world, and look forward to reporting these in subsequent papers.

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APPENDIX A: LABORATORY NAMES

UCSD:CMRG	Cardiac Mechanics Research Group led by Professor Andrew McCulloch, key mentors Drs. Anushka Michailova and Roy Kerckhoffs
UCSD:VBL	Vascular Bioengineering Laboratory, led by Prof. Shu Chien, key mentor Dr. Jason Haga
UCSD:NBCR	National Biomedical Computation Resource, led by Dr. Peter Arzberger, with key mentor Dr. Wilfred Li
UCSD:Vis	Visualization Lab, led by Dr Jurgen Schultz, CalIT2
UCSD:CompChem	Computational Chemistry, led by Professor Kim Baldridge. Has since moved to University of Zurich.
Monash:MesSAGELab	Monash e-Science and Grid Engineering Lab, led by Professor David Abramson
Osaka:AISIELab	Applied Information Systems and Informedia Education labs, led by Prof. Shimojo and Prof. Takemura, with key mentor A/Prof. Susumu Date, Cybermedia Center

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