AC 2008-1155: U.S.-INDIA INTERNATIONAL RESEARCH, EDUCATION, AND INDUSTRY EXPERIENCES FOR STUDENTS IN ACOUSTICS AND NON-DESTRUCTIVE EVALUATION

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U.S.-India International Research, Education, and Industry Experiences for Students

Abstract

The National Academy of Engineering report *Educating the Engineer of 2020* calls for system-wide efforts to align our nation's engineering curriculum and engineering profession with the needs of today's global, knowledge-driven economy with the goal of increasing student interest in engineering careers. As more industries benefit from the economic advantages of a global R&D capability, U.S. engineering teams need to prepare for collaboration across countries and the blurring of national boundaries. Future engineers need to be trained not only in basic engineering skills, but also in managing global research teams. Realizing the importance of training U.S. students to work successfully in global R&D research environments, we obtained a grant from the National Science Foundation. This paper summarizes the project experiences of five students who worked with the faculty members and students at the Indian Institute of Technology, Madras, and industry executives at Larsen & Toubro Limited and Bharat Heavy Electricals Ltd.

Rationale of Proposed Activity for Developing Global Engineers

Preeminence in technological innovation depends on a wide array of factors, one of which is leadership in engineering research, education, and practice. As other nations increase their investments in engineering research and education, the U.S. risks falling behind in critical research capabilities and, ultimately, the innovations that flow from research (National Academy of Engineering, 2005). The nation's ability to capitalize on new knowledge resulting from large investments in life sciences will depend on contributions from engineering. Engineering research is founded on a disciplined approach to problem solving and the application of sophisticated modeling, design, and testing tools to solve problems. The *Educating the Engineer of 2020* report (2005) calls for system-wide efforts to align the engineering curriculum and engineering profession with the needs of today's global, knowledge-driven economy, with the goal of increasing student interest in engineering careers. It has also been recommended that research should be combined with education, thereby training students in critical thinking and research methodologies, as well as providing them with solid engineering skills (National Academy of Engineering, 2005).

Stephen D. Bechtel, Jr., the Chairman Emeritus and Director of Bechtel Group, Inc., (2006) states that, "We must be able to manage and integrate globally constituted, multi-cultural teams that design and procure equipment, materials, and services internationally." He goes on to note, "GE has Jack Welch's 70:70:70 rule. That is: 70% of the business processes, including engineering, are to be outsourced. Of this, 70% is to be sent offshore, and of this 70% will be sent to India." Katehi (2005) has also pointed out the importance of this new approach, saying "By 2050, 8 billion of the 9 billion people on Earth will live in developing countries, and economic growth in these countries will be only 2 percent below the expected economic growth in the developed world. Future engineers need to know how to communicate effectively and think globally and appreciate the impact of social/cultural dynamics on a team environment. They need to develop analytic skills, problem-solving skills, and design skills." In the next two months, Dell will begin building a large PC manufacturing facility in India (Lee, 2006). Kamal Nath, India's Commerce Minister, says, "10 paradigm shifts are taking place simultaneously in

India. Outsourcing is a story of the past. We now want people to see India as a manufacturing base, as the youngest nation with fortunate future demographics." (Kripalani, 2006).

As more industries utilize the economic advantages of a global R&D, U.S. engineering teams need to prepare for collaboration across countries and the blurring of national boundaries. Future engineers need to be trained not only in basic engineering skills, but also in managing global research teams (Pennoni, 1998). Thus, engineering education needs to be drastically altered to give students opportunities to work in international research teams (Wulf & Fisher, 2002, ABET, 2004, Felker, 2003; Engardio et al., 2003; Kripalani and Engardio, 2003). Engineering educators should introduce interdisciplinary learning in the curriculum wherever possible and explore the use of case studies of engineering successes and failures as a learning tool (*Educating the Engineer of 2020*, 2005). These findings lead to the singular premise upon which this project is based: New challenges and opportunities are emerging due to the emergence of global R&D teams and future engineers must be given opportunities to learn how to perform effectively in this market.

Realizing the importance of training U.S. students to work successfully in global R&D research environments, we obtained a planning grant from the National Science Foundation NSF OISE-0439706 during 2004. The goal of the planning grant was to work with faculty members from engineering institutes, industry managers and engineers in India to develop strategies for providing U.S. engineering students with research experiences in global research projects and to document those research experiences for use in constructing new instructional materials for undergraduate students that showcase the integration of research and education in real world situations. The planning grant enabled us to meet managers from Larsen and Toubro Limited (L&T) in Madras, and the John F. Welch Technology Center in Bangalore, as well as with Drs. Ramachandriah and Balasubramaniam, faculty members at IIT Madras, to discuss and finalize the research areas of the potential projects. We found that the U.S. faculty team was particularly strong in the research areas of acoustics, non-destructive evaluation, and case study development, while the Indian faculty team was highly skilled in modeling industrial problems in their laboratories and had excellent relationships with the two companies. We subsequently received an award from NSF to conduct an international research experience for students (IRES) project (OISE# 0623351).

By combining the strengths of both academic teams, we provided five U.S. graduate (M.S./ Ph.D.) students with a comprehensive international research experience in both academic and industrial settings in India. A student from Auburn teamed up with another student from IIT Madras to work in the area of thermal comfort and conducted a research project in partnership with Larsen and Toubro, Madras. Another team of three Auburn students working with their counterparts in IIT Madras conducted two research projects in the areas of non-destructive evaluation in partnership with Bharath Heavy Electrical Limited (BHEL) and an oil refinery. Another Auburn student worked on a remote data synchronization project. In order to disseminate this research experience to a broader audience of students, the results of the research were documented using the case study methodology. These case studies will be used as instructional materials in classes at both institutions. This activity will target a much larger audience of students, familiarizing them with the kinds of global R&D problems that exist, the need for engineering research to solve such problems, and the processes used to solve the problems. Thus, the goals of this project are to provide:

- an intensive research experience for U.S. students working with partners at IIT Madras, a premier engineering institute in India ,
- experience in working as members of an international team for both the U.S. and IIT students,

- industrial research experience for the U.S. students working in industry research laboratories (Larsen and Toubro, Limited and BHEL) in India,
- opportunities for U.S. academics to collaborate with academic and industrial researchers in India,
- opportunities for the researchers to integrate their findings into education through the development of new instructional materials, and
- the excitement of discovery to undergraduate students when they use the resulting instructional materials in their classrooms.

Description of the intellectual collaboration with foreign collaborators

The projects focused on research connected with acoustics and non-destructive evaluation, areas in which Auburn's Dr. Raju, is an expert. Dr. A. Ramachandriah of the Dept. of Civil Engineering at IIT Madras was his counter-part on the acoustics project and Dr. Krishnan Balasubramaniam, the Head of the Center for Non-Destructive Evaluation at IIT Madras, worked with him in that area. Development of the case studies was supervised by Dr. Sankar, who is an expert in that area. Executives from Larsen and Toubro Limited (L&T) and BHEL agreed to partner with this research team in the area of acoustics and Non-Destructive Evaluation.

Larsen and Toubro Limited: Larsen and Toubro Limited is the legacy of two Danish engineers, who built a world-class engineering organization. It is a professionally managed leader in India's booming engineering and construction industry, with sales of $3 billion during 2004. The Engineering Construction Corporation (ECC) division's headquarters campus at Manapakkam, Madras, is acknowledged as an "outstanding corporate campus" and is India's largest construction organization. Seventeen Strategic Business Units (SBUs) drive ECC's business activities to formulate policies, perform marketing functions, and ensure project execution to international benchmarks of quality and speed. The design activities are centralized in the Engineering Research and Design Center (ERDC) located at Madras, India. The EDRC offers engineering, design, and consultancy services in civil, structural, mechanical, electrical, and instrumentation engineering for a variety of projects and industrial structures. With over 350 experienced engineers, architects, and 100 draftsmen, EDRC is the largest and best equipped engineering design office in India's construction industry. Mr. K.P. Raghavan, Vice President of Buildings and Factories Sector, Engineering Construction and Contracts Division, L&T has been the mentor of this project.

Bharat Heavy Electricals, Ltd.: Bharat Heavy Industries Limited (BHEL) is the largest engineering and manufacturing enterprise in India in the energy-related/infrastructure sector, today. BHEL manufactures over 180 products under 30 major product groups and caters to core sectors of the Indian Economy viz., Power Generation and Transmission, Industry, Transportation, Telecommunication, Renewable Energy, etc. The wide network of BHEL's 14 manufacturing divisions, four Power Sector regional centers, over 100 project sites, eight service centers and 18 regional offices, enables the Company to promptly serve its customers and provide them with suitable products, systems and services -- efficiently and at competitive prices. The high level of quality and reliability of its products is due to the emphasis on design, engineering and manufacturing to international standards by acquiring and adapting some of the best technologies from leading companies in the world, together with technologies developed in its own R&D

centers. The greatest strength of BHEL is its highly skilled and committed 42,600 employees.

BHEL has installed equipment for over 90,000 MW of power generation -- for Utilities, Captive and Industrial users.

- Supplied over 2,25,000 MVA transformer capacity and other equipment operating in Transmission and Distribution network up to 400 kV (AC and DC).
- Supplied over 25,000 Motors with Drive Control System to Power projects, Petrochemicals, Refineries, Steel, Aluminum, Fertilizer, Cement plants, etc.
- Supplied Traction electrics and AC/DC locos to power over 12,000 kms Railway network.
- Supplied over one million Valves to Power Plants and other Industries.

Indian Institute of Technology Madras: The IIT Madras is among the foremost Indian centers for both higher technological education and basic and applied research. Its self-contained campus is located in a beautiful wooded land of about 250 hectares in South Madras. The activities of the Institute encompass several departments and advanced research centers in a range of engineering and scientific disciplines, with nearly 100 laboratories organized in a uniquely functional pattern. The Institute performs $25 million worth of sponsored projects and research based industrial consultancy each year. IIT Madras strongly believes in forming strategic alliances with other leading research institutions globally and encourages joint research programs. The area of Measurement, Testing, and Diagnostics has been recognized as a major focus for research effort by the Institute.

Auburn University: Auburn University operates a Sound and Vibration Research Laboratory in the Mechanical Engineering Department, where several faculty members, visiting scholars and graduate students conduct their research. Auburn University's ME Department also has excellent facilities for the characterization of materials and structures using non-destructive techniques. Since its founding, over 20 Ph.D.s and 40 masters students have graduated from these laboratories, conducting research in the areas of acoustics, noise control engineering, non-destructive evaluation, and vibration. Sponsors have included: NASA Marshall; NASA Langley; NASA/JPL; IBM Charlotte, North Carolina; IBM Austin, Texas; the American Gas Association; the US Navy; the National Science Foundation (NSF); the Department of Defense (DOD); and the United Nations Development Program (UNDP), among others.

Integration of Research and Education: Development of Case Studies - Strengths of Auburn University: A major goal of this project is to integrate research into teaching and learning at the undergraduate level and thus infuse education with the excitement of discovery. In order to accomplish this goal, we used the case study methodology to develop new instructional materials that can be used in undergraduate classrooms. The LITEE team (www.auburn.edu/research/litee) works with industrial partners to identify a suitable problem and bring it alive in the classroom by creating a multimedia case study. This is then tested for pedagogical value and content with faculty and students at different institutions. The multimedia case study CD-ROMs make it possible for students to visualize the case study problem and, in some cases, even hear the voices of those charged with making the original decisions. Photos and videos of the machinery and equipment in the actual plants are included. The time span for a typical multimedia case study implementation in a classroom ranges from one day to five weeks, depending on how the instructor decides to structure the class. The tasks are broken into three phases -- before the class, during the class, and after the class. Prior to the initial class session, the instructor selects the case study to be assigned and provides competency materials to the

students. Student preparation for the case discussion involves reading the competency materials and the case studies, and then writing an analysis that follows an instructor-prescribed format including role-playing activities. Once the class session has begun, the instructor reviews the competency materials and the case study. Then the instructor divides the class into teams and initiates teamwork exercises to help improve group interactions. Thereafter, the students present their findings. The benefits of the LITEE multimedia case studies have been evaluated by experts in the College of Education at Auburn University. In addition, the evaluators have performed longitudinal studies to identify the benefits that accrue from using this case study methodology. The results of the evaluation have been published in 20 journal articles and 37 conference proceedings (www.auburn.edu/research/litee). These studies have established that the benefits of implementing case studies in engineering classrooms include:

- Bringing theory and practice together in classrooms
- Facilitating the development of students' higher-order cognitive skills and problem solving skills
- Encouraging active teamwork among students
- Bringing the excitement of real-world problems into classrooms
- Offering detailed information on the importance of science and engineering theories in solving real-world problems
- Improving written and oral communications skills
- Fostering a change in learning environment that encourages female and minority students to persevere and succeed in engineering programs
- Offering a method that has a lasting impact on student learning, as measured by improved grades in subsequent semesters

The IRES project goals and educational objectives are shown in Table 1.

Project Goals (What will we do?)	**Educational Objectives (What will students achieve?)**
Develop a case study that introduces engineering students to the complexity of real-world problems in collaborative global engineering R&D projects	*The students will be expected to:* *- learn how companies use innovative research in the design of products and systems* *- learn how companies form and manage teams to design engineering products and services in globally dispersed R&D units.* *- work in teams, thereby enhancing their team building, interaction, and interdisciplinary skills.*
Develop instructional materials that help visualize research on global R&D issues	*The students will experience:* - *Synchronous learning opportunities such as triggering learning interest, learning from others, and working in teams.* - *Asynchronous learning opportunities such as solving challenging problems, accessing vast information sources, learning discovery-based educational experiences safely, and enhancing peer-to-peer education.*

Table 1: Project Goals and Educational Objectives

Project Timeline and Execution

Five students were recruited during Fall 2006 to participate in this project. A brochure was developed and distributed to all the graduate students at Auburn University. The five students were selected based on their interest in working on a global project, their availability during Summer 2007, and their resumes. They were from Electrical Engineering, Computer Science, Mechanical Engineering, and Architecture disciplines. Of the four U.S. citizens who

participated in this project, three had never traveled outside the U.S., one was a minority. We recruited an Indian national to participate in the project so that he can provide local logistic support to the student team and make the transition to a different culture easier. All of them stayed at the campus at IIT Madras between May to July 2007.

After arriving at Madras on May 23, 2008, the students were taken to L&T by one of the faculty members. L&T was a strong partner in this project and welcomed all the students to their facilities at Manapakkam, Madras, and provided possible projects that they can work on. The faculty members at IIT Madras also provided other project opportunities to the students. The students chose the projects that best met their research experiences and needs.

A detailed schedule was worked out so that Dr. Sankar will start the project and then return to the U.S. and then Dr. Raju will arrive later and close the project. The schedule followed during the project is shown as Appendix A. Video conferencing facilities available at IIT Madras and LITEE, Auburn University were used on a bi-weekly basis to track the progress on the project. The students made a final project presentation to IIT Madras faculty members and to L&T executives during July 2007. This formally completed the project.

Details of Projects Completed by Students during Summer 2007

1. **Data Synchronization Project:** A graduate student with computer science background worked on the data synchronization project presented by L&T. The current system of communication was not appropriate for the demands and time constraints of each project executed by L&T. The biggest issues were with the Work Order forms that each job site submitted to the main office for approval. The current communication system allowed each job site to manually pack and send their information over the Internet. This process required human intervention and had a long lag time between updates. So if a work order was submitted it wasn't be ready until the next day or next login. L&T was looking for a solution that removed the user from needing to manually transmit information, enhance security and reduce turn around time. The student had to solve a communication problem, learn the pitfalls of transferring information over the internet, and learn about secure communications techniques. The student worked with L&T's software engineers to develop a system that automates the task of synchronizing the databases. The main advantage of this system was the removal of the remote site employee from having to manually transmit information. He developed code in C Sharp to help the project team. He also developed a multi-media case study based on this project.
2. ***Feasibility Study of In-Situ Weld Inspection for Induction Pressure Welding Process:*** There were three main problems faced at the inspection stage of induction pressure welding process at BHEL. The first problem was with the inspection time of the welds. The time taken for the cooling and inspection is more than the time for set up and the welding. This made the processing stagnant at the inspection stage in the production environment. So BHEL is looking for a faster method of inspection. The second problem encountered by the operators at inspection was the inaccessibility of welds. It was tough to access some areas of piping for inspection. The third problem was with the pasty welds or kissing bonds. When the crack surfaces stay in very close contact with each other then the bond between the two surfaces of the crack is called

a kissing bond. This is a very dangerous bond. The welds appeared to be fused and pass the ultrasonic inspection but failed at the work site. Lack of bonding and mismatch are the types of defects commonly appearing on these welds. Figures 1 shows an example of induction welding.

Induction coil around the pipe during the induction welding operation

Figure 1: Induction coil around the pipe during the welding operation

3. Acoustic Emission Testing: Process control, process monitoring, structural health monitoring and non-destructive testing requirements are evolving into complex, often distributed, systems. To date, no general methodology for system architecture or design has been developed. Developing such an approach would provide many benefits such as shorter design cycle, improved reliability and an easier path to demonstrating the technical benefits to production and maintenance management. Monitoring the acoustic emission due to corrosion and structural factors in large above ground storage tanks (LASTs) was identified as an important problem. In order to minimize material cost, LASTs have floors made of mild steel that is susceptible to both inner and bottom or base-side surface corrosion. Corrosion reduces the floor thickness and hence increases the stress around the corroded areas. With the adoption of acoustic emission testing (AET), the health monitoring of oil tanks has become a much easier task. For AET, the oil tank has to be shut down completely for 24 hours. This time gives the oil inside the tank time to cool down and settle. It also allows the ingoing and outgoing pumps to stabilize and become dormant. The reasoning behind the shutdown is to allow all acoustic generators to settle down in hopes of achieving better data monitoring integrity. Typically 4 to 8 sensors are optimally placed around the tank to establish triangulated diagnosis. Cables are then ran from each sensor approximately 30m from the tank to a data acquisition and analysis station. This setup usually takes around 4 hours to complete due to having to route the cables around tanks, pipes, and other obstacles. The sensors are monitored for around 2 hours. After data collection, the data is analyzed and results are produced. AET is not cheap. It can actually wind up costing up to 50 lakh ($13,000) depending on tank size. Even though it may be more expensive than cleaning and inspecting, AET only causes the tank to be offline for a maximum of

36 hours. The oil inside the tank is still usable. The greatest benefit is that as long as the located tank damage is not more than 70% of the initial floor thickness, the required draining and inspection can be pushed back additional years.

4. Thermal Comfort of Buildings in Two Cities: Real estate is at an all time high in Madras and Bangalore and the objective of this project was to make apartments more comfortable for their occupants. In order to evaluate the performance of the materials used in these apartments, Larsen&Toubro conducted thermal comfort analysis of two buildings in both cities. Results provide a comparative analysis to be used in both understanding the process of thermal comfort analysis & differences in architectural trends as varied by location (Figure 2).

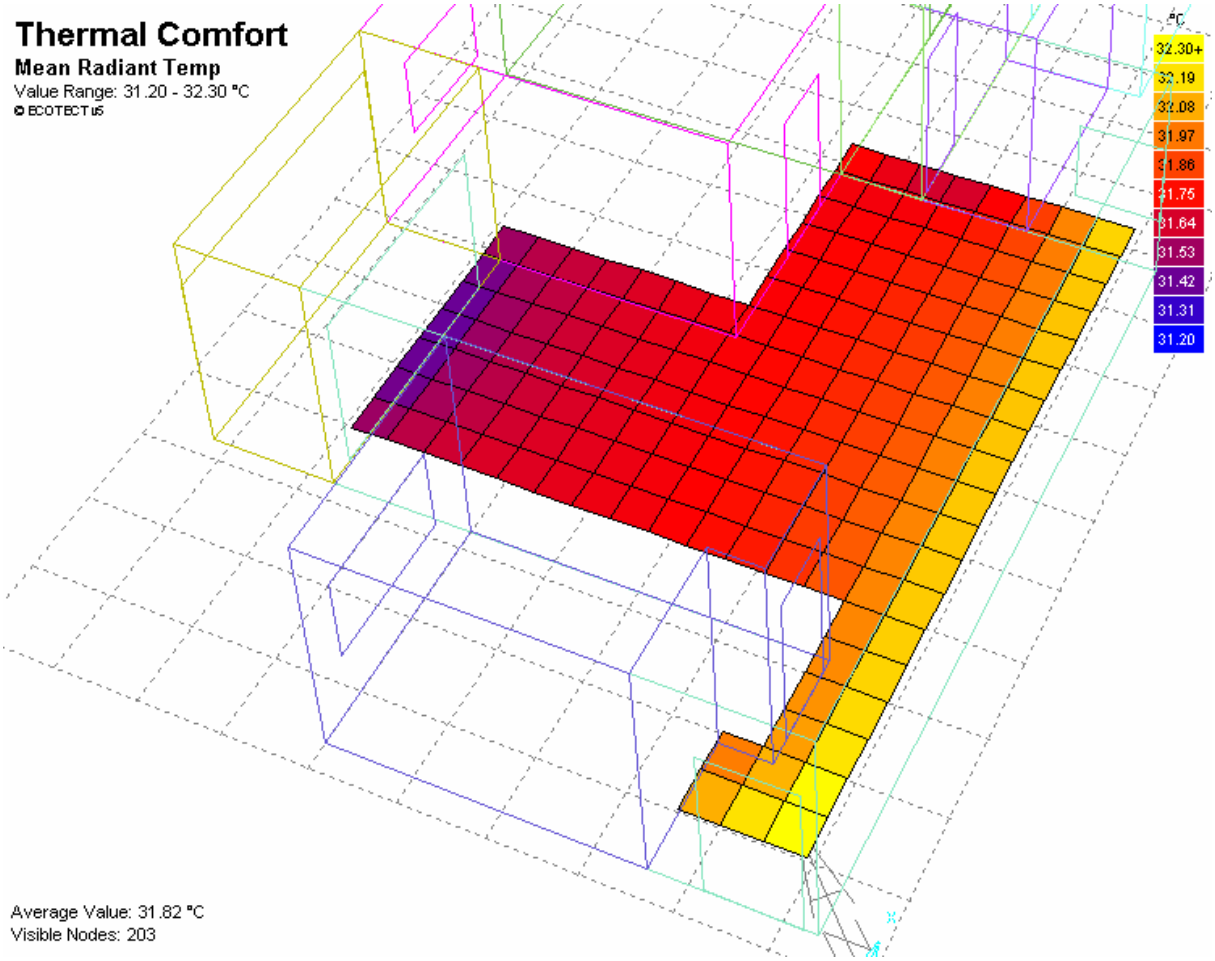

Figure 2: Thermal Comfort Analysis of a Building

Feedback on Research Experiences

The students presented their final projects to L&T executives and to the faculty members at IIT Madras. They received feedback on their work. During the fall semester, their research work was converted into four distinct case studies. Of these, one case study, "***Feasibility Study of In-Situ Weld Inspection for Induction Pressure Welding Process,"*** has been already tested in a Mechanical Engineering senior level class. The other case studies are still being finalized and will be tested in classes in the future.

The students were also requested to provide feedback on their international research experience. A questionnaire was developed in order to obtain their feedback. The results of the responses from four students are shown in Table 2.

Question	Mean
The experience offered me a chance to use theory I had learned earlier and practice together to develop a research project.	1.3
The experience helped develop my higher level cognitive skills.	1.3
The experience allowed me to gather sufficient information to develop a LITEE case study/ research paper	1.3
The experience has the potential to motivate students to pursue engineering education.	1.5
The experience has motivated me to look for potential global cooperation in the future.	1
This project at India enabled me to enjoy and learn from it.	1.3
The experience was helpful in informing me about the research efforts at IIT India and L&T.	1
The experience was helpful in informing me about the research efforts of LITEE/ AU to improve educational methodologies and pedagogies.	1
The experience and the project leaders provided sufficient information to conduct the project.	1
This program really helps AU students obtain real-world experiences while in college.	1
The experience met my expectations.	1.3
The experience was presented at a level compatible with my background and experience.	1.3
The research proceeded at just the right pace.	1.7
The support provided by the Indian project team (IIT Madras and L&T) was very helpful.	1.3
The travel/cultural information provided during Spring 2007 were helpful in dealing with reality.	1.7
The International Research experience was well organized and well presented.	1.7
Due to this experience, I feel well informed/prepared to work on other global research projects in the future.	1

Rating: 1-Strongly agree; 2-Agree; 3–Neutral; 4-Disagree; 5-Strongly disagree

Table 2: Feedback from Students

The mean of all the responses were below 2 indicating that the students either strongly agreed or agreed to the questions. The quantitative results show that the students felt they were well informed/ prepared to work on other global research projects in the future due to this experience. A student stated:

> *I got the chance to work with people in another nation and see their customs and ways. I also learned how they work and get the advantages/disadvantages of outsourcing to a foreign nation. It was fun and eye opening experience.*

Another student stated:

> *We were exposed to an extremely different style of life than the one we are used to both inside and outside of the academic research environment. Also, we were able to work on an important and interesting global engineering problem with an extremely competent group of foreign researchers, giving us a different perspective to the problem. This was a truly amazing experience both in terms of gaining real world global life perspective and research/career development.*

A third student stated:

> *I improved my strength in doing purely technical research and work with other world class NDT facilities.*

A faculty member under whom one of the students was conducting research in the U.S. stated:

> *I wanted to provide some feedback on the student's experience in India this past summer. I can see a real difference in his attitude and motivation in my research laboratory since his return. I believe that his experience in India helped him to make that significant step from being a student to being an engineer.*

Summary and Conclusions

The feedback from the first year of the project has been very positive and we look forward to conducting two more years of this project. We plan to report the results of the research projects that will be conducted in the future years. We hope that this helps other researchers conduct similar International Research Experiences for their students so that engineering students can gain significant global research experiences while still in school

Acknowledgements

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Appendix: Timeline

19th May	Dr. Sankar arrives at Madras – phone conversation with Dr. Krishnan & Dr. Ramachandraiah
23rd May	Dr. Sankar meeting with Dr. Krishnan and Dr. Ramachadnraiah, IIT Madras
23rd May	U.S. student team arrives
24th May	Meeting of the U.S. Student Team at IIT Madras (noon)
25th May – 1st June	Visit to L & T / BHEL/ other companies
26th and 27th May	**Discussion at IIT Madras / Finalization of projects, timelines, & student teams**
June 2nd	Dr. Sankar leaves for the U.S.
28th - 1st June	Case study at Jain Housing with documentation (L&T project)
	- Experiments
	- Theoretical Analysis
	- Videograph/ photos as needed
2nd - 10th June	Work at L & T & another company (Dr. Krishnan's project)
	- Study the drawings
	- Data collection on materials used and cost
	- Based on earlier case study identify potential comfort issues to be solved
	- Procedure followed in a corporate organization to solve such issues
	- Identification of the decision making process
	- Criteria in arriving at a decision - parameters that are given emphasis
	- Videograph/ photos as needed
11th - 15th June	Case study at Bangalore (for L&T project)
	- Experiments
	- Theroetical Analysis
	- Identification of comfort issues
	- Videograph/ photos as needed
15th June	Initial version of CD-ROM of the case study for all projects
	- Developing a computer program for the above model
	- Analysis
	- the decision making process involved
	- Develop a model based on the above studies
	- Students submit mid-term report to Drs. Raju/ Sankar/ Krishnan/ Ramachandraiah
16th - 18th June	Supportive study and discussions at L&T
24th - 26th June	Documentation, analysis, and development of case study
27th - 29th June	Work at L & T
	- conducting interviews with Engineers, Architects and Managers
30th - 4th July	Study of different material options applied to the Bangalore housing and Jain housing
	- Theoretical studies
	- Computer simuation studies
11th - 21st July	Finalization of project, case study CD-ROM ready
	- Dr. Raju arrives in India/ works with the team
	- Final reports/ CD-ROM due from students
	- **Sign off on project by Drs. Raju/ Krishnan** - **Final presentation to L&T executives**
23rd July	Students leave Madras