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Preparing Students for Global Research Experiences: US–India Summer Projects*

CHETAN S. SANKAR[1], P. K. RAJU[2], HOWARD CLAYTON[1]
[1] *Department of Management, Auburn University, AL 36849, USA. E-Mail: sankacs@auburn.edu claythr@auburn.edu*
[2] *Department of Mechanical Engineering, Auburn University, AL 36849, USA, E-Mail: rajupol@auburn.edu*

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 for the purpose of increasing student interest in engineering careers. We developed an innovative global internship program for which students researched real-world problems in another country and then documented their research experiences by means of multi-media case studies. This paper describes the methodology, collaboration among US and Indian universities in order to conduct the internship programme, the project timeline and execution, an overview of the projects and an evaluation of the value of the experience to the participants. The evaluation shows that the students perceived that they are more informed about global issues, are better prepared to deal with the future, obtained real-world experiences, and improved their higher-order cognitive skills due to their participation in this project.

Keywords: global internship project; case studies; real-world experiences; engineering education research; interdisciplinary

INTRODUCTION

PRE-EMINENCE IN TECHNOLOGICAL INNOVATION depends on a wide array of factors, including leadership in engineering research, education, and practice. As other nations increase their investments in engineering research and education, the US risks falling behind in critical research capabilities and, ultimately, the innovations that flow from research [1, 2, 3]. The nation's ability to capitalize on new knowledge resulting from large investments in 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 2005 report, *Educating the Engineer of 2020,* calls for system-wide efforts to align the engineering curriculum and engineering profession with the needs of today's global, knowledge-driven economy for the purpose of increasing student interest in engineering careers. It has also been recommended that research be combined with education, thereby training students in critical thinking and research methodologies, as well as providing them with solid engineering skills [4, 5, 6, 7, 8].

Stephen D. Bechtel, Jr., Chairman Emeritus and Director of Bechtel Group, Inc., has stated, 'We must be able to manage and integrate globally constituted, multi-cultural teams that design and procure equipment, materials, and services internationally' [9]. He went 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 [10] 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'. Kamal Nath, India's Commerce Minister, said, '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'. [11].

As more industries utilize the economic advantages of a global R&D, US engineering teams need to prepare for collaboration across national boundaries. Future engineers should be trained not only in basic engineering skills, but also in managing global research teams [12, 13, 14, 15]. Preparing for the next generation of engineers to enter the world with a competitive advantage requires inventive, resourceful and continually evolving methods. These methods are expected to instill parallel intercultural communication, global resource management, and interpersonal professional training alongside the requisite and non-negotiable training on technically related subjects

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of the discipline. Thus, engineering education needs to be drastically altered to give students opportunities to work in international research teams [16, 17, 18, 19, 20, 21, 22, 23]. Engineering educators should introduce interdisciplinary learning into the curriculum wherever possible and explore the use of case studies of engineering successes and failures as learning tools [24].

These findings lead to the premise upon which this project is based: new challenges and opportunities are emerging due to the creation of global R&D teams, and future engineers must be given opportunities to learn how to perform effectively in this market. By working on projects in a foreign country and documenting their research experiences, students gain the opportunity to appreciate the complexity of real-world problems. A 'multiplier effect' can be realized when the documentation of the research experience is done in the form of a case study because the resulting cases could eventually be used to educate other students. Thus, we define the goals and educational objectives of this project as shown in Table 1.

In this paper we describe the methodology we chose to achieve the objectives and the collaboration among U.S. and Indian universities in the joint venture. We also describe the project timeline and its execution, an overview of the projects, as well as an evaluation of the value of the experience to the participants.

Methodology chosen to achieve project goals and educational objectives

This section reviews the different methods that could be used to achieve the project goals and educational objectives and then describes the methodology that was chosen for this project.

It is possible to achieve the goals listed above through distance education [25, 26]. Schwartz et al. [27] described two Master's level programmes on global energy data available on the Internet. Gotel et al. [28] described the lessons from running software development projects across three globally distributed educational institutions. Richardson et al. [29] used a global studio project to coordinate the work of software engineering students across four countries into a single project. Montoya and Moore [30] used a Web-based tool to integrate aspects of social responsibility into an introductory course. An advantage of distance education is its relatively low cost, which results from the non-requirement of international travel. However, it is not easy for students to investigate a research problem, discuss alternatives with engineers in the company, and come up with a solution. In addition, the students will not get an exposure to cultural issues if they don't travel to another country. We opine that distance education would be especially suitable if the students had an ongoing relationship with a company in a foreign country and used this method to augment their research experience.

A case study approach is also possible. A case is typically a record of an issue that engineers or managers have faced, together with surrounding facts, opinions, and prejudices upon which decisions have to depend. These real and particular cases are then presented to students for analysis, and discussion about the type of action that should be taken. After the students have arrived at a solution, their decisions, results, or proposals are compared to the solution that was actually adopted by the company that had the problem. There are many examples in the engineering education literature that document the success of case studies. Ball et al. [32] discuss the experience faced by students working across two universities to develop a case study based on a hypothetical food manufacturer expanding its market for its products. Mehalik et al. [31] discuss a project to develop products for sustainable human development by collaboration across the USA and Brazil. Hariharan et al. [33] describe two case studies in which immersive experiencing of a novel concept led to a better understanding of it. Vivas et al. [34] describe a learning architecture for developing a series of case-based studies that are linked by a common thematic basis. McNair et al. [35] discuss a case study based on cross-cultural, cross-disciplinary collaboration in a capstone design course and show that the students became aware of the complexities posed by such collaboration. Yadav

Table 1. Project goals and educational objectives methodology chosen to achieve project goals and educational objectives

Project Goals (What will we do?)	Educational Objectives (What will students achieve?)
Introduce engineering students to the complexity of real-world problems in collaborative global engineering R&D projects	The students will be expected to: – appreciate how companies use innovative research in the design of products and systems – become more intrigued with unfamiliar approaches to accomplishing challenging tasks through collaboration with practitioners – discover new engineering techniques that are helpful in overcoming obstacles
Develop instructional materials that help visualize research on global R&D issues	The students will: – transfer their knowledge to other students using case-study methodology – improve their higher-order cognitive skills – work in teams, thereby enhancing their team building, interaction, and interdisciplinary skills

et al. [36] discuss the types of cases utilized in ethics education and show that well-designed experiments are needed to understand the value of this approach. Despite the utility of case studies they do not provide all the benefits that accrue when students physically visit a foreign country and work there.

Snellenberger et al. [37] recommended that engineering students undergo an on-site technology development project in a company and that employees in companies undergo professional education. Lloyd and Rosenberg [38] described a global mechanical engineering program through students undergoing courses in different global locations. Gerhardt [39] has used a programme to provide 200 exchanges annually to undergraduate engineering students. Our approach to providing US students with real-world and international experience follows along similar lines adopted by these three latter researchers. The goals of this project were accomplished by having our students work with university faculty members and company executives in India to research a problem in an industry and obtain valuable research skills on a global engineering problem.

Translating research results into everyday teaching practice is notoriously difficult as described by Turns et al. [40]. These authors state that researchers need to consider the task of making research products useful for faculty and instructors as a design problem and develop suitable strategies. We accomplished this goal by requesting that students develop a multi-media case study as the end product of their global internship project. We have made these case studies available to instructors and students and expect that these materials can be integrated into the engineering curriculum.

Collaboration among US and Indian organizations

In order to achieve their goals, the project team partnered with several companies and universities in India.

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 $7 billion during 2007. The Engineering Construction Corporation (ECC) division's headquarters campus in Manapakkam, Madras, is acknowledged as an 'outstanding corporate campus' and is India's largest construction organization. The design activities are centralized in the Engineering Research and Design Center (ERDC) also located in Madras, India. The ERDC offers engineering, design, and consulting services in civil, structural, mechanical, electrical, and instrumentation engineering for a variety of projects and industrial structures. With more than 350 experienced engineers, architects, and 100 draftsmen, ERDC is the largest and best-equipped engineering design office in India's construction industry. Senior-level executives at this company mentored the student participants in this project.

The John F. Welch Technology Center (JFWTC), Bangalore, is General Electric's first and largest Research and Development Center outside the US. An integral part of GE Global Research, the $80 million infrastructure at JFWTC is a hub of technology, research and innovation for GE worldwide. The focus of the Center is to facilitate the growth of GE businesses through innovation and the use of cutting-edge technologies. The Bangalore center has excellent facilities in the area of digital radiography, non-destructive evaluation, and imaging. The General Manager (Operations) was the mentor for the students in this project.

Gandhi Rural Rehabilitation Center (GRRC), located in the small village of Alampoondi in the Villupuram district of Tamil Nadu, is a vital resource for the surrounding rural community. What began in 1983 as a weaving workshop for the physically challenged has evolved over two decades into an organization whose activities include income generation through weaving, tailoring and embroidery, identification, treatment and rehabilitation of people with physical and mental disabilities, and research and development in the field of indigenous medicines and plants. The director of this center worked with the students.

Indian Institute of Technology Madras (IIT) 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 area of about 250 hectares (618 acres) in South Madras. The Institute performs $25 million worth of sponsored projects and research-based industrial consulting each year. Two faculty members from the departments of civil engineering and mechanical engineering worked with the student teams in guiding them in the areas of acoustics, non-destructive testing, and thermal comfort.

Auburn University operates a Sound and Vibration Research Laboratory in the Mechanical Engineering (ME) Department, where several faculty members, visiting scholars and graduate students conduct their research. Auburn University's ME Department also has excellent facilities in acoustics and non-destructive evaluation of materials and structures. The Department of Management hosts the information technology programme and graduates 2–4 Ph.D. and 10 Master's students each year. Faculty members from the departments of mechanical engineering and management led the project team.

The National Institute of Technology, Trichy was started in 1964 with a view to developing outstanding engineers and technologies. The Center for Energy, Environmental Science, and Technology (CEESAT), a unit within NIT Trichy, specializes in researching alternative energy resources and partnered with the Auburn University students and faculty members.

Table 2. Timeline of the project

Tasks	Fall Semester	Spring Semester	Summer	Fall Semester
Advertise project, Invite applications & select candidates				
Prepare for the global internship & make travel arrangements				
Travel to site, conduct research project & develop case study				
Refine, get acceptance from company & publish case study				
Evaluate project & provide feedback				

PROJECT TIMELINE AND EXECUTION

The project timeline extended over four semesters and is summarized in Table 2.

During the fall semester, a brochure was developed to advertise the project and solicited students to attend an information session. Project details were provided during this session and interested students were interviewed to match them with the project requirements. Ten students were recruited to participate in this project during Summer 2007 and Summer 2008. The students were selected based on their interest in working on a global project, their availability during summer, and their resumes. They were drawn from the disciplines of electrical engineering, computer science, mechanical engineering, economics, building sciences, textile design and architecture. Of the students who participated in this project, four had never travelled outside the US and one was a minority. We recruited an Indian national to participate in the project so that he could provide local logistic support to the student team and make the transition to a different culture easier.

A course map (Figure 1) was developed to prepare the students for the project experience in the spring and summer semesters. The outcomes expected of this project are to develop leadership skills and capabilities, provide opportunities to be an innovator, and exhibit ability to share, access, and interpret large volumes of information.

At the base level of the course map two case studies, which are introduced to the students during the spring semester, are depicted along with their embedded concepts. By analyzing the Mauritius Auditorium Design case the students learn and apply concepts from fluid mechanics and acoustics, project management and decision making. When they analyze the Lorn case study the students are exposed to the concepts of codes,

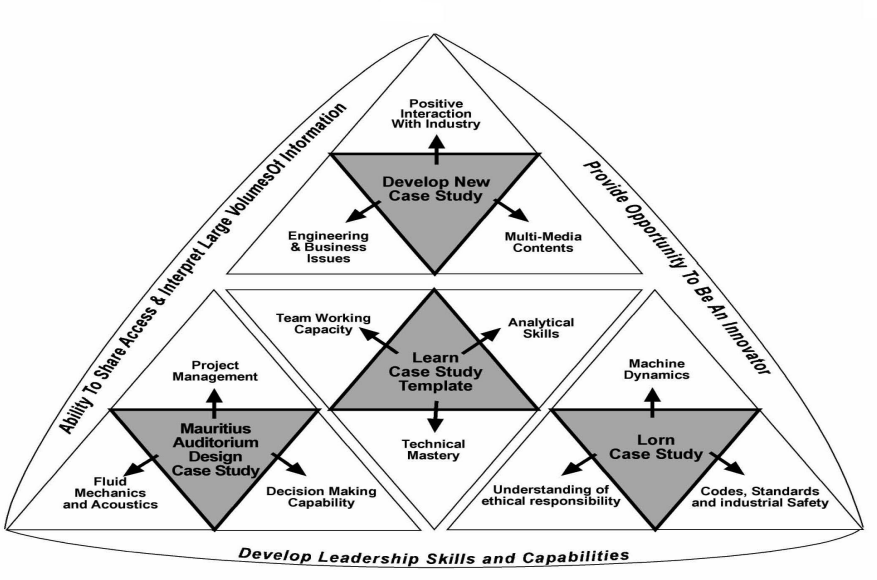

Fig. 1. Course map.

standards and industrial safey, ethics and machine dynamics. These case studies are available to students at www.liteecases.com After they have understood the utility of case studies in improving engineering education, they are then trained to use a case study development template so that they can convert the outcomes of their future research project into a case study format [41]. During this semester, the students work in teams in all the projects, thereby enhancing their team working skills.

The outline of the spring semester course is as follows:

- Week 1: Teamwork exercises; Information on previous projects
- Weeks 2 & 3: Lectures about working with industries and real-world projects
- Weeks 4 & 5: Lectures on engineering fundamentals
- Weeks 6 & 7: Analysis of first case study (Mauritius Auditorium Design case study)
- Weeks 8 & 9: Preparing the presentation using a team-working station
- Week 10: Talk from alumni members about their experiences and projects
- Week 11: Lecture on basics of ethics and legal implications of engineering and business decisions
- Week 12: Analysis of the Lorn case study
- Week 13: Preparing the presentation for the case study
- Weeks 14–16: Experience in using a case study template.

During the summer semester, the students travel to India and work with a company to study a global R&D problem in partnership with other students. They use their technical and engineering skills to understand and research a problem provided by the company. They visit the company's facilities and are provided with a list of projects that could be worked on during the summer. In consultation with faculty advisors, the students choose projects that coincide with their research experiences and interests. During their two month stay in India, the students carefully study the research problem to gain full understanding of it. Then they simulate the problem in laboratories at the collaborating institutions and come up with potential solutions. It is arranged for one faculty member from the US to be in India to start the project before returning to the US and for him to be later replaced by another faculty member from the US to close the project. Video conferencing facilities available at IIT Madras and Auburn University are used when needed to track progress on the project. Depending on the project, a faculty member, from India, with expertise in the research problem, visits the company during the project period to provide guidance, work with the industry partners and resolve any problems. At the end of the project the students make a final presentation to Indian faculty members and company officials. Once the company officials accept the research results, the students begin documenting the problem and solutions as a case study. They then submit the case study to the company for review and approval before disseminating the materials. In the review process the company is asked to make any modifications to the case study they deem necessary and to provide the appropriate permissions so that the case study can be released for academic use. As part of developing the case studies, the students prepare an instructor's manual that includes assignments and possible solutions.

A faculty member with expertise in statistical methods was recruited to evaluate the outcomes of the project. He travelled to India during the second year of the project and had intensive discussions with the companies and students. He also developed and administered a questionnaire to evaluate the project.

SUBSEQUENT SEMESTERS

Each student team's project is regarded as complete when they have generated a case study. The case study is further refined by the faculty members and graduate students at the Laboratory for Innovative Technology and Engineering Education (LITEE), Auburn University, and disseminated through the website: www.litee.org These case studies are then available to instructors and students at Auburn University and other institutions for use in classrooms.

Whenever possible, the students who developed the case studies are also encouraged to be present in the undergraduate classes when the case studies are implemented for the first time. Based on the feedback they receive from the class, the LITEE staff further refines the case studies. Past studies [42, 43] have established that implementing case studies in engineering classrooms bring theory and practice together and facilitate the development of students' higher-order cognitive skills and problem solving skills.

Summary of research projects conducted by students

A summary of the projects that the student teams conducted during Summer 2007 and 2008 in the areas of information technology, non-destructive evaluation, acoustics, and thermal comfort are described below.

Data synchronization project, Summer 2007

This project conducted at L&T describes the improvements in software systems that made it possible for work order forms at remote job sites with limited Internet access to be submitted to the main office for approval. The student had to solve a communication problem, learn the pitfalls of transferring information over the Internet, and

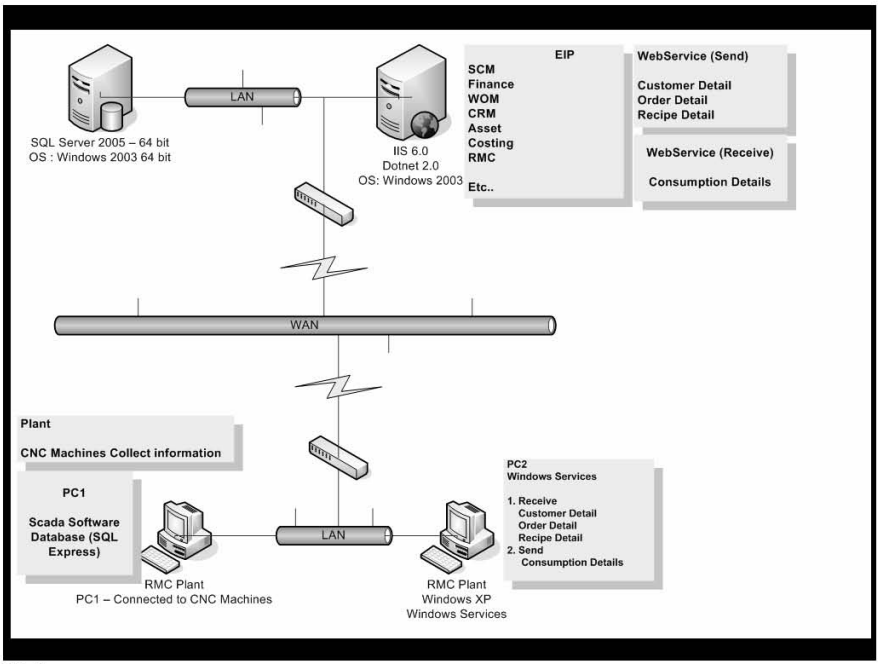

Fig. 2. Implementation of data synchronization project.

learn about secure communications techniques. The student worked with L&T's software engineers to develop a system that automated the task of synchronizing the databases. The student developed code in C Sharp to help the project team.

The L&T project team eventually incorporated the student's code into an actual system developed and delivered in January, 2008 (Figure 2).

A plant located approximately 20 Km from the headquarters used to mix cement from various raw materials and load it in trucks. Before being automated, all orders for mixing concrete were managed by hand, which caused inconsistent production and led to quality problems. With the new data synchronization system in place, all orders are now processed in an automated batch order mode: order information, including customer and recipe details, is sent from the headquarters via a broadband connection to the plant and received by a client computer (Figure 2). That computer automatically releases the correct quantities of raw materials from various storage silos to be mixed with each order. All orders are processed and quickly fulfilled without human intervention. This removes the possibility of human errors and guarantees the quality of each order. When the system completes an order, it sends a notification to the headquarters to inform it of the amount of materials used. Thereby, reorder of raw materials can be processed quickly and efficiently. The benefits of the new system have greatly increased the company's sales and profits. During early 2008, the concrete plant was sold to another company, and this company has been discussing with L&T the possibility of implementing a similar data synchronization system across its 57 plants around India.

Feasibility study of in-situ weld inspection for induction welding process, Summer 2007

This project describes the three main problems presented at the inspection stage of the induction pressure welding process at a large boiler manufacturer and methods to resolve them. The first problem was with the inspection time of the welds. The time taken for the cooling and inspection was more than the time for setup and welding, leading to delays in production. Therefore, the company was looking for a faster method of inspection. The second problem encountered by the operators at inspection was the inaccessibility of welds. It was difficult to access some areas of piping for inspection. The third problem was with the pasty welds, where the welds appeared to be fused and passed the ultrasonic inspection but failed at the work site. Lack of bonding and mismatch between the pipes that are being welded are the types of defects that

Fig. 3. Induction coil around the pipe during the welding operation.

commonly appeared on these welds. Figure 3 shows an example of induction welding. A student participant studied this problem, identified potential alternatives to solve the problem, discussed them with management, and developed a case study to document the problem and solution.

Acoustic emission testing, Summer 2007

This project describes the process used to adopt acoustic emission testing (AET) to check for any leaks in oil tanks. Typically, four to eight sensors are optimally placed around the tank to establish triangulated diagnosis. Cables are then run from each sensor to a data acquisition and analysis station. After data collection, the data are analyzed and results are produced. AET can actually cost up to 50 lakh rupees (US$110,000), 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 project also designed a prototype wireless system that can be used for monitoring the tank. The project team developed a case study that discusses the problem and potential solutions. The case study included a decision support system matrix that provides students with the ability to evaluate the alternatives based on a set of criteria (Table 3). This matrix is provided as a spreadsheet and students can modify the values and see how the results will vary.

Thermal comfort of buildings in two cities, Summer 2007 and 2008

The price of real estate is at an all-time high in major cities in India, 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, the team conducted thermal comfort analysis of two buildings in two cities. The student team considered the following materials: reinforced concrete, solid concrete block, clay brick and hollow concrete block. Results provide a comparative analysis to be used in both understanding the process of thermal comfort analysis and differences in thermal comfort based on the building material used for the exterior walls. Figure 4 shows the mean radiant temperature (MRT) readings for a building in Hyderabad during May 2008 using the four materials studied in this project.

Table 3. Decision support system matrix for acoustic emission testing case study

PROJECT REQUIREMENTS	*Alternative 1 -- Wired Interface*	*Alternative 2 -- Wireless Interface*	Importance Ranking by Auburn University	Importance Ranking by IIT Madras	Overall Weighting	Percentage of Total
Transmission Distance	1	1	4	1	4	16.0%
Signal Integrity	1	1	5	1	5	20.0%
Data Rate	1	1	4	1	4	16.0%
Transport and Setup	1	1	5	1	5	20.0%
Ease of Integration	1	1	3	1	3	12.0%
Cost	1	1	4	1	4	16.0%
				Total:	25	100.0%
OVERALL RATING OF ALTERNATIVE	25	25				
Total Overall Rating	*50*					
RELATIVE OVERALL RATING OF ALTERNATIVE AS PER DSS	**50.0%**	**50.0%**				

First, read through the case study analyzing the information carefully. Then, derive a meaningful relative rating between 1 and 5 for each highlighted cell. Once you do this, the DSS computes an overall relative rating for each alternative. The alternative with the highest overall relative rating is the one that you prefer for the project.

1 - Being Least Important
5 - Being Most Important

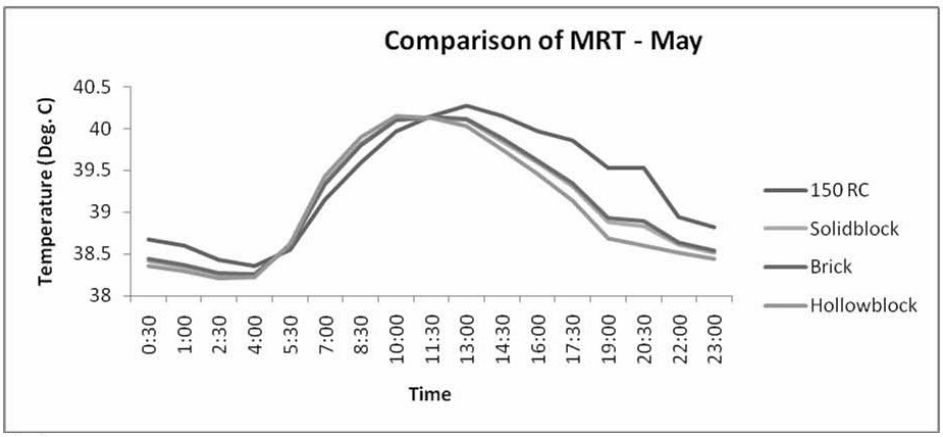

Fig. 4. Comparison of mean radiant temperature (MRT) at Hyderabad with four materials for outside walls.

The student team made several recommendations to L&T based on the research performed at the sites. L&T management has adopted several of these recommendations in future building designs. The student team also developed a case study that provides a cost/comfort analysis of the different options and the ability to simulate the options used for construction of the exterior walls of apartment buildings.

Multi-media case studies have been developed based on these projects and are available for use in classrooms. These can be accessed from www.liteecases.com

EVALUATION RESULTS

During both summers, the students presented their final projects to the company executives and to the faculty members at IIT Madras, NIT Trichy, and at Auburn University. They received feedback on their work. Among the case studies developed, one of them, 'Feasibility Study of In-Situ Weld Inspection for Induction Pressure Welding Process', has already been tested in a senior-level mechanical engineering class and was well received [44]. The other case studies will be tested in classes in the future.

The students were also requested to provide feedback on their international research experience by completing a survey at the end of the trip. The results of the responses from the ten students are shown in Table 4.

The means of all the responses (on a 5-point scale of which 1 is the lowest and 5 the highest) were above three, indicating that the students either strongly agreed or agreed with survey statements. They provided a response of between three and four for four questions. These show that they had some difficulty in collecting appropriate information to complete the case studies (Statements 3 and 13) and had difficulties in adjusting to a very different culture in India (Statements 14 and 15). Students specifically mentioned crowds, traffic, toilets, and dust as major concerns that they were not prepared for. The responses to all other

Table 4. Feedback from students

Number	Statement	Mean
1	The experience offered me a chance to use theory I had learned earlier and practice together to develop a research project.	4.3
2	The experience helped develop my higher level cognitive skills.	4.4
3	The experience allowed me to gather sufficient information to develop a LITEE case study/research paper	3.6
4	The experience has the potential to motivate students to pursue engineering education.	4.5
5	The experience has motivated me to look for potential global cooperation in the future.	4.2
6	This project in India enabled me to enjoy and learn from it.	4.3
7	The experience was helpful in informing me about the research efforts at IIT India and L&T.	4.4
8	The experience was helpful in informing me about the research efforts of LITEE/AU to improve educational methodologies and pedagogies.	4.1
9	The experience and the project leaders provided sufficient information to conduct the project.	4.6
10	This program really helps AU students obtain real-world experiences while in college.	4.7
11	The experience met my expectations.	4.3
12	The experience was presented at a level compatible with my background and experience.	4.5
13	The research proceeded at just the right pace.	3.4
14	The support provided by the Indian project team (IIT Madras and L&T) was very helpful.	3.6
15	The travel/cultural information provided during the program were helpful in dealing with reality.	3.4
16	The international research experience was well organized and well presented.	4.3
17	Due to this experience, I feel well informed/prepared to work on other global research projects in the future.	5.0

statements with averages between four and five show that the students were provided an opportunity to apply theory to practical problems, improve their higher-order cognitive skills, and motivate them to pursue engineering education and global opportunities. In summary, the project provided them the ability to obtain real-world experiences while at college and prepared them well to work on global projects in the future. The students also provided extensive comments about the project and discussed the project results with the external evaluator. The quantitative and qualitative comments were analyzed in order to find out how well the educational objectives stated in Table 1 above were met.

DISCUSSION OF RESULTS

We have set out the educational objectives of this project as the appreciation of how companies use innovative research in the design of products and systems, become more intrigued with unfamiliar approaches to accomplishing challenging tasks through collaboration with practitioners, discover new engineering techniques that are helpful in overcoming obstacles, transfer knowledge to other students using case-study methodology, improve higher-order cognitive skills, and work in teams, thereby enhancing team-building, interaction and interdisciplinary skills. How well were these educational objectives achieved in terms of student performance in the projects and evaluation of results?

Appreciating how companies use innovative research in the design of products and systems

All of the projects involved the design of new systems and/or software in order to solve the stated problem. The solutions were documented using case studies that are available from www.liteecases.com Student responses to statements 1 (mean of 4.3), statement 7 (mean of 4.4), and statement 17 (mean of 5.0) showed that this objective was well met. A student commented: 'I got an up-close experience as to how construction processes work in India. L&T was excellent and very enjoyable to work with'. Another student stated 'Meeting with executives at a major Indian company was exciting. We talked about India, the US, globalization and how the world was changing, for over an hour. That conversation was amazing to me since I have read and heard so much about globalization, but being in that room I saw it happening and gained a new perspective on it'.

Becoming more intrigued with unfamiliar approaches to accomplishing challenging tasks through collaboration with practitioners

The US students had to work with faculty members and students from India in order to complete the projects. Answers to statement 5 (mean of 4.2), statement 7 (mean of 4.4), statement 10 (mean of 4.7), statement 14 (mean of 3.6), and statement 16 (mean of 4.3) indicate that this objective was achieved to an agreeable or strongly agreeable level. A student said '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'.

Discoveing new engineering techniques that are helpful in overcoming obstacles

A student who worked on the synchronization project was able to develop code that was eventually converted to an actual implementation. The recommendation of the thermal comfort team was accepted by L&T management. In addition, the student team had observed and commented on innovative practices adopted by L&T in pouring concrete in multi-storied buildings. The student who worked on the non-destructive testing methodologies was able to devise new techniques for finding faults in welds and was able to publish the results [45].

Students reported that they achieved these objectives well, as shown by their responses to statements 1 (mean of 4.3), statement 4 (mean of 4.5), statement 10 (mean of 4.7), and statement 17 (mean of 5.0). A student commented, 'I improved my strength in doing purely technical research and work with other world class NDT facilities'. Another stated, 'This project is much more challenging and beneficial than studying abroad in Europe or Mexico. I do believe that an international experience opens my eyes and I have become more humble with my lifestyle upon returning. I would describe my experience as positive as a whole'.

A faculty member under whom one of the students was conducting research in the US offered this reflection:

> 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.

Transferring their knowledge to other students using case study methodology

Students were able to develop four different case studies and these are available at the www.liteecases.com website. Some of the student teams completed their case studies while they finished their project work in India, whereas others provided draft case studies which had to be refined further. The students perceived that they had obtained an agreeable or strongly agreeable experience in developing case studies as shown by responses to statement 3 (mean of 3.6), statement 8 (mean of 4.1) and statement 17 (mean of 5.0).

They had difficulty reconciling the expectations

from the hosts about the research aspect of the project and the educational aspects of the case studies. A student stated that 'Our hosts wanted to make a very intensive, highly technical case study to present to L&T engineers and project managers at the end while we were trying to direct the study towards undergraduate students. While we definitely wanted technical information in the study, we wanted to make it understandable and usable for the students and not orient it toward experienced executives in the construction industry'.

Improving higher-order cognitive skills

Students reported that they were able to use the theory they learned to develop the research project (Question 1, mean of 4.3) and that the experience motivated them to look for potential global cooperation in the future (mean of 4.2, statement 5). They also perceived that their higher-level cognitive skills improved (Question 2, mean of 4.4). In addition, they perceived that they obtained real-world experiences while in college (mean of 4.7, Question 10). A student stated, 'A benefit of this program is working internationally, being able to travel, and see development and globalization up close'. Another student stated the following about the experience:

> We were left to our own resources in order to function and learn in a new environment. Being able to work at our pace and schedule so we could travel when we wanted to. No longer feeling uncomfortable, having the confidence to go to new places, talk to new people, try this or that; to me, that is what makes travelling character-building. You can't really prepare a student going from the US to India—you have to expect the unexpected—that's why I like to travel.

Working in teams, enhancing team building, interaction and interdisciplinary skills

Students were provided with multiple opportunities to develop these skills. In the US, the Indian students were the alien; in India, the US students were the aliens. Since the Indian students worked along with the US students in India, it provided an opportunity for the students to form a diverse team. The responses to statements 5 (mean of 4.2), 10 (mean of 4.7), 14 (mean of 3.6), 16 (mean of 4.3), and 17 (mean of 5.0) indicate that the students felt well enough informed to work on other global research projects in the future. A student made the following observation:

> 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.

Another student stated, 'A lot of the people we met and worked with at different times were great people that were very interesting'. A third student noted, 'The time I spent at GRRC was some of the most rewarding time of my life and some of the most difficult'. Another student stated:

> The Indian student saved our lives many times in the village. If someone is planning to take a trip there, I would suggest having a local guy there. It would be very difficult to settle in without some guidance from a local person.

LIMITATIONS AND POSSIBLE IMPROVEMENTS

There were several limitations in conducting the project. Even though the project organizers intended to define the projects and case studies before the team left for India, it was difficult to do so. The industry executives in India felt more comfortable choosing the projects once they saw the student team. In addition, there were changes made to projects because promised accommodations at IIT Madras did not materialize and changes had to be made at the last minute. Some of the students reacted to the changes negatively. A student made the following comment:

> If the program were more organized, we could have 'hit the ground running'. We had mixed signals from L&T and had great difficulty obtaining information. In the spring semester, the projects should have been organized better.

Another issue dealt with the culture shock that the students experienced in conducting the project in India. Some of them had never left the US, did not have real-world experiences, and expected that the project would work without obstacles. They also found it difficult to adjust to the local culture. Also, they had difficulty understanding the Indian accent. Some of them commented this way:

> 'A faculty member in India never said a whole lot—wish he will communicate more'. 'We received different programme goals from faculty in India and the US. Students need to be warned about heat, lack of A/C, power cuts, scarcity of English-speaking people, mosquitoes in rural areas, different kind of toilets, pollution and trash'.

Overall, the students felt the programme was beneficial and wished more engineering students would attend such programmes. They agreed with the following comments from one student:

> More engineering students should have come—they would benefit more.
>
> You need a better way of getting the word out to students—more students need to hear about it.

SUMMARY

This paper reports on the experiences of students who conducted research projects in India and developed case studies based on those

experiences. The feedback from the project has been very positive. The students perceived that they had become more informed about global issues, are better prepared to deal with the future, obtained real-world experiences and improved their higher-order cognitive skills. Some of the issues that were identified are the differences in culture and the difficulty in communication. The innovation of this study is that the students converted the results of their research projects into multi-media case studies. This project provided a research experience in India, thereby training students in critical thinking and research methodologies, as well as providing them with solid engineering skills. In doing this they communicated their research projects to others who do not have the ability to travel globally. Students gain effective team working skills and global research experiences by participating in these projects thus fulfilling some of the expectations of engineering programmes [46]. Widespread adaptation and implementation of such projects might provide opportunities for students to learn how to perform effectively in the global market.

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Chetan S. Sankar is the Thomas Walter Professor of Management at the Auburn University's College of Business. His research interests focus on researching innovative practices to integrate teaching, research, and outreach both locally and globally (www.litee.org). He has published more than 150 papers in journals, book chapters and conference proceedings. He has won awards for research and teaching from the Society for Information Management, iNEER, Decision Sciences Institute, American Society for Engineering Education, Frontiers in Education, and the Project Management Institute. He is the editor of the *Decision Sciences Journal of Innovative Education* (www.dsjie.org). He has been the principal or co-principal investigator of several grants from the National Science Foundation budgeted at more than $2.2 million.

P. K. Raju is the Thomas Walter Professor in Mechanical Engineering at Auburn University and a Fellow of the American Society of Engineering Education. He has made significant research contributions in acoustics, nondestructive evaluation, and engineering education, resulting in award-winning and significant breakthroughs. He has received a total of $7.7 million in funding, including grants from industries, the United Nations, the National Science Foundation, and other U.S. Federal agencies. He has published 8 book chapters and 160 papers in journals and conference proceedings. He has developed an excellent team at Auburn University that has successfully developed and implemented multimedia case studies at several universities. He has organized numerous national and international conferences and is the director of the Auburn Engineering Technical Assistance Program (AETAP). In order to promote engineering education research, he also edits and publishes the *Journal of STEM Education: Innovations and Research* (www.jstem.org).

Howard Clayton, an associate professor in the College of Business at Auburn University, is an expert on statistical methods with over 35 years teaching experience at both the K-12 and university levels. He has published many articles on statistical methods in journals. He currently serves as an evaluator on the research teams of two NSF funded grants, as well as an evaluator for the NSF sponsored Center for Advanced Vehicle Electronics (CAVE) at Auburn University.