

AC 2007-656: DESIGN AND IMPLEMENTATION OF A CASE STUDY AND MULTIMEDIA COURSEWARE FOR THE MULTIDISCIPLINARY CLASSROOM

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Abstract

The Mauritius Auditorium Design multimedia case study was developed based on real-world problems that arose during the construction of the Swami Vivekananda International Convention Center on the island of Mauritius by an Indian construction company. Design issues arose due to differences in the cultural backgrounds of the designers and users of the polyvalent hall located in the convention center. Four different solutions were possible to solve the acoustic problem that arose.

The multi-media software package provides background information about the companies, architects, and acoustic consultants, as well as documents that describe the problem with the design and the alternative solutions proposed. Various tools enhance the student's learning experience:

- Instant access to common *Glossary* terms via mouse-over
- *Interactive reverberation simulator* to demonstrate design and material effects on the reverberation time of a small room.
- *Video interviews* with company managers and engineers explaining the problem, alternatives, design issues, and business ethics that must be considered in global engineering endeavors
- Exposure to a *real-world problem* in the classroom
- *Interactive sound simulator* for learning about the effects of reverberation time on the use of the hall for different events such as conferences, rock concerts, and automobile shows
- Direct access to desired content through the *categorized Sitemap*
- *Interactive* decision support system (DSS) for use in evaluating design alternatives

The multimedia software offers an effective way for engineering students to see how global engineering design decisions are made and understand the importance of acoustics in auditorium design. Included multimedia content was compiled by an international team of graduate students, undergraduate students, and faculty members spanning two universities on two continents. Executives and engineers at the international engineering firm responsible for this project also provided interviews and materials for developing this case study.

This case study and the associated CD-ROM are available to students and faculty members through an e-commerce website. Widespread use of this case study at several institutions will provide further feedback on the value of multi-media case studies in improving engineering education.

Introduction

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 research¹⁹. 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 skills¹⁹.

Stephen D. Bechtel, Jr., the Chairman Emeritus and Director of Bechtel Group, Inc., states that, "We must be able to manage and integrate globally constituted, multi-cultural teams that design and procure equipment, materials, and services internationally"². 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." Katchi has also pointed out the importance of this new approach:⁸

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 India¹¹. 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"⁹.

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 teams¹⁵. Thus, engineering education needs to be drastically altered to give students opportunities to work in international research teams^{3,4,10,18, ABET, 2004}. 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 tool¹⁹. These findings lead to the singular premise upon which this paper 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.

A methodology to provide students an opportunity to learn about challenges in global markets is for them to use multimedia courseware in the classrooms^{1,3,6}. A case study was developed for either a laboratory or classroom setting with the intent to improve a student's learning experience and knowledge retention rate. This paper documents the development of a multi-media case study which provides a deep understanding of acoustics engineering and global project management concepts to engineering students.

The next section describes the case study that was developed by students and faculty members from two academic institutions – one in the U.S., the other in India – documenting a real-world

problem that happened in a multinational company. Then, we describe the multi-media developed to enhance the value of the case study. This case study was implemented in an undergraduate class that contained both engineering and business students. The results of testing the case study in this classroom are provided. The paper concludes by discussing the lessons that were learned in developing and implementing such a case study.

Case Study Description

The Mauritius Auditorium Design (MAD) case study is based on real-world problems that arose at Larsen and Toubro Limited, an Indian construction company, during the construction of the Swami Vivekananda International Convention Center on the island of Mauritius. Design issues arose due to differences between the cultural backgrounds of the designers and users of the polyvalent hall located within the convention center. The case study offers an effective way for engineering students to see how global engineering design decisions are made and understand the importance of acoustics in auditorium design.

Larsen and Toubro (L&T) 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, Chennai, 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), also located in Chennai. ERDC 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 draftspersons, ERDC 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 was instrumental in providing the case study content and releasing the multimedia courseware for use in classrooms.

L&T faced an acoustical problem that arose as a result of their work on the Swami Vivekananda International Convention Center project in Mauritius. The convention center site measures about 13 acres and is located on a mountainside. The complex is equipped with a polyvalent hall, amphitheater, conference center, meeting rooms, and an atrium with a banquet hall. L&T worked with the construction firm Shapoorji and Pallonji to build the complex during 2004 in time to host the U.N. conference that is held once every four years in a small island nation. The cost of the building was Rs. 80 crores (\$15 million) and from conception to completion took 18 months. The project was finished in January of 2005 and the U.N. successfully conducted its conference at this facility.

The polyvalent hall met the needs of the conference exceedingly well and received rave reviews from the participants. The hall, originally designed to accommodate conferences, trade shows, exhibitions, seminars, sporting events, and concerts, performed well with sound levels of up to

94 dB by design, a condition that far exceeds the requirements used for concert performances in India. The Vice President of Mauritius stated, “This center will be one of the gems of Mauritian architecture, and will stand out as an example of Indo-Mauritian cooperation.” Stephen Schwartz from the U.S. Embassy commented, “[A] fabulous building, and quite an achievement.” After the UN conference was over, the convention center became available for hosting other activities to generate revenue and, being a multifunctional hall, it had to be able to serve a wide range of different activities appropriately. Variable acoustic devices were installed in order to accommodate the increasing variety of events and acoustical preferences.

However, L&T faced a major problem shortly after the UN conference in the polyvalent hall with a scheduled rock concert. During the rehearsal on February 10, 2005, the rock musicians found that the hall’s audio quality was unacceptable. An L&T engineer who was present on the occasion measured the decibel level and found that the rock band performed at a sound level of 104 decibels (dB), which was well above the design level and was probably the reason for the discomfort experienced by the rock musicians. The polyvalent hall had a problem with high reverberation, and the unexpectedly high intensity sound levels introduced by the additional PA systems brought in by the rock musicians in front of the stage created noticeable acoustical discomfort, especially for those on stage. The glass panel fronting the VIP gallery at the rear of the hall was visibly vibrating. The listeners also reported a lack of clarity and felt the sound was distorted. Substantial portions of the back wall were bare and lacked any acoustical treatment, and these reflected a part of the energy back towards the source, creating additional reflected energy. When the reflected energy detected was loud and late-arriving, this was resulting in unwanted reflections. The clients wanted to resolve the issue as quickly as possible in order to avoid generating a lot of negative publicity.

L&T engineers and managers consulted with members of the faculty at a university to evaluate a new material that could potentially be used to resolve the problem and determine the reverberation time of the auditorium if this material was used. Four alternatives were generated that could solve the problem ranging in cost from \$33,000 to \$67,000. Anil Chuttur, Director, Chuttur & Partners Limited, Mauritius and Mr. Elco de Jong, his consultant, had to develop a list of criteria to evaluate the alternatives and make a choice among the four alternatives. The client and L&T also had to decide who would pay for the modifications given that the acoustic performance requirements were not explicitly stated in the contractual documents.

Features of the Multimedia Courseware Development Environment

A combination of several factors make this project unique: the engineering field of the related case study, the target student population for implementation, the team of designers involved with production of the courseware, the multimedia product created, and the method of case study and multimedia courseware implementation.

Related Engineering Field

Previous case study applications have been developed for use in industrial, materials, mechanical, electrical, and computer engineering courses¹⁶. This project sought to successfully

design and implement multimedia courseware to solve an acoustical engineering and global project management problem.

Target Student Audience

Multimedia courseware for the engineering classroom is most often developed for a homogeneous student population. This courseware was specifically designed for use by both engineering and business students. Mixing the target audience meant that principles and processes had to be conveyed using basic concepts as building blocks via multiple types of examples. A hybrid audience also increases the possible number of students who can successfully use the software. Given the concepts involved with this case study, the following groups would benefit from this courseware:

- Undergraduate classes in building science and architecture
- Graduate class in building acoustics and noise control
- Undergraduate class on functional design of buildings
- Undergraduate classes in business and engineering

This case study exposes students to basic acoustic design principles and global engineering practices. In addition, engineering and building design students gain familiarity with managerial decision making and business ethics concerns by analyzing this case study. Even though this courseware targets students of higher education, application at the high school level is attainable. High school students could use this software to familiarize themselves with issues related to global engineering projects.

Development Team Composition

Both the case study and multimedia courseware were compiled by an international team of graduate students, undergraduate students, and faculty members spanning two universities on two continents. Executives and engineers at L&T also provided interviews and materials for developing the case study and courseware.

Deliverables: Case Study and Multimedia Courseware

The first objective of developing this course material is to improve the skills of the students on the following:

- Problem-solving, given global engineering considerations
- Engineering design, considering acoustics
- Decision making, given multiple alternatives to solve a design problem

A secondary objective is to bring real-world business and engineering issues to classrooms, thereby contributing to the strong educational foundation expected of every engineer.

The courseware provides background information about the companies, architects, and acoustic consultants involved with the project. Also available are the documents which describe the

acoustic design problem and the four alternative solutions proposed. Various tools are provided to enhance the student's learning experience:

- Instant access to common Glossary terms via mouse-over
- Interactive reverberation simulator to demonstrate design and material effects on the reverberation time of a small room.
- Video interviews with company managers and engineers explaining the problem, alternatives, design issues, and business ethics that must be considered in global engineering endeavors
- Exposure to a real-world problem in the classroom
- Interactive sound simulator for learning about the effects of reverberation time on the use of the hall for different events such as conferences, rock concerts, and automobile shows
- Direct access to desired content through the categorized Sitemap
- Interactive decision support system (DSS) for use in evaluating the design alternatives.

Provided below is a screen shot from the DSS, filled with values to support selection of the final design solution chosen by L&T. Also given is an explanation of how these final values were derived.

DECISION SUPPORT SYSTEM MATRIX

CUSTOMER REQUIREMENTS	Importance Rating as per Original Design of Hall	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Importance rating once the acoustic problem is solved	Improvement Factor: Column G / Column B	Importance Ranking by Chuttur & Partner's Ltd.	Importance Ranking by Larsen & Toubro (L&T)	Overall Weighting	Percentage of Total
Aesthetics	5	1	3	2	5	5	1.0	5	2	10	5.1%
Fire Safety	3	1	5	2	3	5	1.7	5	5	41.67	21.1%
Fixture Permanence	3	1	3	5	3	5	1.7	3	2	10	5.1%
Cost	3	5	4	3	2	3	1.0	3	4	12	6.1%
Performance	2	3	1	4	5	5	2.5	5	5	62.5	31.6%
Multipurpose Fixture Functionality	3	1	3	1	1	5	1.7	5	5	41.67	21.1%
Ease of Implementation	3	5	3	3	5	5	1.7	3	4	20	10.1%
Shipping Method	3	5	3	3	3	3	1.0	1	5	5	2.5%
OVERALL RATING OF EACH ALTERNATIVE		475.833	578.833	556	698.167					Total: 197.8	100.0%
<i>Total Overall Rating</i>		2308.833333									
RELATIVE OVERALL RATING OF EACH ALTERNATIVE AS PER DSS		20.6%	25.1%	24.1%	30.2%						

The four alternatives were ranked by L&T on their interrelationship to the requirements of Chuttur & Partner's Limited.

Table 1 – Decision Support System Solution

How the Ranking System was Devised

<i>Criteria</i>	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Aesthetics	Not Appealing	Okay	Did Not Blend With Interior	Aesthtically Appealing
Safety(fire)	Unsafe	Fire Retardant	Further Treatment Req'd	Okay
Fixture Permanence	Temporary	Okay	Very good	Good
Cost	\$11,000	\$32,000	\$45,000	\$69,000
Performance	Okay	No Guarantee	Good	Best
Multipurpose fixture functionality	No	Yes	No	No
Ease of implementation	Easy	Involves Skilled Labor	Involves Skilled Labor	Easy
Shipping	Not Required	Required	Required	Required

Using the information provided by L&T, each criteria was evaluated and a numerical weighting system was devised:

- 1 = No, Not Required
- 3 = Okay, Required
- 5 = Appealing, Best

Table 2 – Explanation of DSS Solution Values

Implementation of the Case Study and Multimedia Courseware

This case study is designed for use by groups of students. The groups defending the alternatives must consider both technical (material and acoustical) and non-technical (cost, risk, and ethical) issues involved with the project in their arguments. The suggested team format for classroom management of the case parallels the method used by corporate management to review current operations, forecast short and long-term goals, and select an appropriate solution. The team approach also encourages students to learn from each other and helps them improve both the affective and cognitive dimensions of their learning style. When the students research the case seeking answers to the questions raised, they read much of the background material included. This case study is designed to provide a very engaging and critical analysis of a real-world issue.

A useful approach to teaching this case study is for students to first study the case objectives and then be required to answer the questions individually. This gives the instructor a basis for individual student evaluations. Once team assignments have been made, team members can compare their answers to the questions relating to their team’s assignment. If the answers vary, team members must agree upon a consensus and work together to come up with a solution. It is also helpful for each team to prepare a formal presentation of the solution, playing the roles of the engineers and managers involved in the problem. This enables students to understand the problem more deeply and they often become very excited about the importance of acoustics and engineering in solving real-world problems.

Results from Implementation in a Classroom

Since this multimedia case study only became available in April 2006, so far one institution has implemented it in the classroom. Seventeen (17) undergraduate students from both business and engineering disciplines used this courseware as part of an introductory engineering course during 2006 at a local university.

First, each of the three groups made its presentation to the class defending one of the three options that was available to the management. Next, the management team exited the room to

meet and discuss the presentations it had seen. Finally, this team returned to the classroom and made a presentation that showcased their solution to the problem. This team had to defend its selection of alternatives based on both technical and non-technical aspects of the problem.

Following classroom implementation, the instructor administered both perceptual and subjective questionnaires to all students. The obtained results are detailed in the following section.

Feedback from Users

The students provided open-ended feedback on the case study that revealed the following themes as its strong points: its emphasis on global issues, introduction to acoustics engineering, video interviews with managers/engineers, and cross-disciplinary topics. The students wrote that they learned a great deal about multinational issues and the way companies operate on a global basis. Their recommendations for improvements in the case study focused on providing the students with a written version of the case study and providing more detailed information on the alternatives. Student feedback encouraged the authors to develop other case study materials similar to this that focus on global issues and engineering topics.

Direct Assessment of Student Learning

A questionnaire provided an evaluation mechanism for student feedback on the use of this case study in this junior level class. The students in this course held majors across various fields and came from the colleges of engineering and business. The questionnaire contained 35 objective questions with a 5 point Likert scale ranging from “1: Strongly disagree” to “5: Strongly agree.” The respondents circled a letter on the scale from **1** to **5** which most closely corresponded to their response to each of the 35 items. Because the 35 questions yielded substantial reliabilities for five clear concepts or constructs, the analysis for the evaluation was organized according to the following five constructs: (a) important and valuable, (b) perceived skill development, (c) instructionally helpful, (d) self reported learning and (e) intrinsic learning and motivation. Earlier studies have validated these constructs^{2, 4, 5}. Cronbach Alpha values were computed for these constructs. These values range from 0 to 1, with a value close to 1 indicating that the items coalesce together well enough to represent the construct. There are several opinions on acceptable levels of Cronbach alphas. For example, Nunnally (1967) proposes an alpha of 0.80 and higher, whereas Treacy (1985) suggests a value of 0.7 or higher.

The Cronbach indices of reliability for the five constructs were as follows: (a) important and valuable (alpha = **0.824**), (b) perceived skill development (alpha = **0.934**), (c) instructionally helpful (alpha = **0.908**), and (d) self reported learning (alpha = **0.869**). The high value of their alphas (indicated by bold lettering) assures us that averaging the items under the first four constructs provides a good measure of those constructs. Scaled values for the four constructs were computed by averaging the responses across the items identified as best representing those constructs. Table 3 defines the items that comprise each construct. Table 4 gives the means and standard deviations for the defined constructs. These means represent the students’ reactions to the case study and courseware.

Constructs	Items – (number of associated survey items)
Important and Valuable	Successful at bringing real-life problems to the session (1) Challenging (1) Helpful in learning difficult concepts (1) Helpful in transferring theory to practice (1)
Instructionally Helpful	Easy to comprehend (5) Well organized (2) Useful (1)
Perceived Skill Development	Identify (5) Integrate (1) Evaluate (2) Express (1) Interrelate (3)
Self-Reported Learning	Improved understanding (3) Learned new concepts (2) Learned From others (1)

Table 3: Mapping of Significant Constructs and Questionnaire Items

Constructs	Important and Valuable (mean, s.d.)	Instructionally Helpful (mean, s.d.)	Perceived Skill Development (mean, s.d.)	Self-Reported Learning (mean, s.d.)
Mean (standard deviation)	4.3529 (1.0)	3.9191 (0.9)	4.0735 (1.0)	4.0784 (1.0)

Table 4: Means for Constructs in Evaluation

Given that the scores fall on a 5-point continuum with a score of 5 representing the highest possible response and a score of 3 representing the midpoint, the means are on the positive side of the continuum for all four significant constructs. The composite results indicate that, as a whole, the students had a positive reaction to this case study. In particular, the students felt that the case study was both important and valuable and instructionally helpful. They also perceived an improvement in their cognitive skills and self-reported learning. These results indicate that the students perceived significant gains in both cognitive and affective domains of learning as a result of participating in this case study implementation experience.

Further Enhancements

The initial courseware as evaluated has since undergone various changes to address what learners perceived as weaknesses. Items added to Version 1.1 of the courseware to further support the learning objectives of the case study include the following:

- *Courseware Objectives* – provides an overview of the concepts introduced and tools provided
- *Effects of Reverberation Time on Music* (Flash application) – provides audio samples of both classical and rock music as reverberation time changes

- *Reverberation Time Simulator* (Java Applet) – a design tool for simulating reverberation given specific design constraints for a room
- *Navigation Menu* – now has both color and font-size differentiation between modules and items

These additional design features are expected to produce an even more favorable evaluation of the case study when next implemented in the classroom. This case study and the associated CD-ROM are available to students and faculty members through an e-commerce website. Widespread use of this case study at several institutions will provide further feedback on the value of multi-media case studies in improving engineering education.

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