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Use of Multimedia Case Studies for Teaching Acoustics

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Abstract

Faculty members teaching acoustic courses feel that there is a strong need to bridge the gap between theory and practice. Engineering acoustic course assignments tend to focus on oversimplified representations of acoustic problems that provide a good understanding of the concepts involved, but do not expose the students to real-world issues. This paper demonstrates the use of a multimedia case study in teaching auditoria acoustic concepts via a global real-world problem. It also discusses the design and development of the case study and presents details of the classroom implementation and evaluation aspects. The classroom implementation of this case study helped improve students' higher-order cognitive, team-working, and problem-solving skills. In addition, students also reported the case study methodology to be a beneficial learning experience.

Keywords: case study, real-world issues, acoustic concepts, learning experience.

1. Introduction

The National Academy of Engineering's report *Educating the Engineer of 2020* calls for system-wide efforts to align our engineering curricula and profession with the needs of today's global, knowledge-driven economy, with the goal of increasing student interest in engineering careers (National Academy of Engineering, 2015). Many engineering students develop a greater appreciation of engineering technologies in their curriculum if they are able to see examples of real-world issues that were dealt with by engineering professionals in the course of their daily work. Past research has shown that the use of multimedia case studies in engineering classrooms is beneficial in reaching these goals, particularly because it enhances students' higher-order cognitive skills, self-efficacy, problem-solving skills, and ease of learning by exposing them to realistic simulations of real-life situations (Raju & Sankar, 1999; Mbarika, 2003). Working through these case studies provides an understanding of the relationship of the fundamental concepts to real-world problems. To enhance the understanding of the concepts of auditorium room acoustics, we therefore developed the *Mauritius Auditorium Design* case study based on a real-world problem that occurred in the industry. This paper discusses the development of the case and its implementation to teach the basics of auditorium room acoustics via the case study methodology and provides evaluation results for this implementation. The results of this study will help universities around the world connect their course work and research to real-world issues and projects (Wang & Lau, 2009; Celmer & Vigeant, 2009).

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2. The Need For New Instructional Methodologies

Faculty members teaching acoustics have been experimenting with methods to bridge the gap between theory and practice, thus improving the curriculum for some time (Lamancusa, 2006; Gee et al., 2013; Neilsen et al., 2012). The major goals of these courses are for students to develop a good understanding of engineering science fundamentals, as well as improve their higher-order thinking and problem solving abilities (Heller et al., 1992; Skudrzy, 1980; Acoustical Engineering Course, 2015). Earlier studies have shown that case studies are a good way to address these issues (Herreid, 1994; Sankar et al., 2008). Previously used at business and medical schools, the Case Method has become a good model for effective learning and gaining the attention of the student audience. Case studies have also been found to be successful in professional development programs (Borko, 2004; Dori & Herscovitz, 2005; Lewis et al., 1998).

A case study typically represents a record of a technical and/or business issue that has actually been faced by managers, together with the surrounding facts, opinions, and prejudices upon which management decisions have to depend. These real and particularized cases are presented to students for considered analyses and open discussion. Ultimately, students must decide what type of action should be taken. The fundamental principles underlying the case study method of teaching were summarized by Barnes et al. (1994) as:

1. *The primacy of situational analysis:* Analysis of some specific situation forces the student to deal with the situation "as is" and not as it "might be."
2. *The imperative of relating analysis and action:* The traditional academic focus is on knowing, while the practitioners' focus is on action. The case study method of instruction seeks to combine these two activities.
3. *The necessity of student involvement:* The active intellectual and emotional involvement of the student is a hallmark of the case study method. That involvement offers the most dramatic visible contrast with a stereotypical lecture class.
4. *A nontraditional instructor role:* The instructor's role when using case studies is not so much to teach as to encourage learning. Instructors become facilitators and must be both teachers and practitioners.
5. *The development of an administrative point of view:* Students develop an understanding of the problem from a holistic point of view and not from simply the engineer's perspective.

Keeping these fundamentals in mind, we developed a case study with the following research objectives.

- Illustrate the fundamentals of acoustics in a real-world application.
- Improve students' higher-order cognitive skills, team-working skills, perceived learning, and attitude toward learning acoustics in the process of solving the real-world problems presented.

This paper describes how the research objectives are achieved in the following sections. Section 3 briefly discusses the development of the case and describes the case study. Section 4 discusses the most important fundamental principles as far as how they are applied in the design of room acoustics, and their use in the case study. It also illustrates the different multimedia technologies used to demonstrate these fundamentals in the case study. Section 5 discusses the classroom implementation of this case study, including the student assignments provided in the class.

Section 6 presents an evaluation of the case study. It examines in detail the constructs of interest that were evaluated and how teaching these skills are important for students' understanding of the fundamentals and how they apply to real-world situations. It also provides both quantitative and qualitative data from the evaluation results. Section 7 discusses the implications of using this approach and how it can change the way we teach acoustics, and the final section summarizes the important conclusions that can be drawn from this research.

3. Development And Description Of the Mauritius Auditorium Design Case study

Faculty members and students from the business and engineering colleges at Auburn University work together through the Laboratory for Innovation and Engineering Education (LITEE) to develop case studies based on real-world problems. In the summer of 2005, a group of faculty members and students from Auburn spent two months in India working with faculty members and students of Indian Institute of Technology Madras, Chennai, India. They documented their projects in the form of a case study. This particular case was developed by students from both universities working with staff from Larsen & Toubro of Chennai, India, on an acoustical problem they faced while designing a large auditorium.

A new international convention center on the island of Mauritius, Africa, was built by Larsen & Toubro, a large Indian construction company. This convention center was intended to accommodate conferences, trade shows, exhibitions, seminars, sporting events, and concerts. A United Nations conference held during January 2005 was a great success. The polyvalent hall of the conference center was scheduled to host its first rock concert in February 2005, but during a rehearsal, the musicians complained about the sound quality not being up to expectations. Sound quality had not been an issue during the U.N. convention, but the loud music was causing problems. Fig 1 shows an external and internal view of the polyvalent hall.

Fig 1: External and internal view of the polyvalent hall

A representative from Chuttur & Partners Limited, a company who managed the conference center, called Larsen & Toubro wanting to know how to solve the problem. Originally, there had been no specific sound requirements when the center was conceived, and Larsen & Toubro was under no legal obligation to solve the acoustic problem. Therefore, a decision first had to be made as to whether the company would work to solve the acoustic problem and, if so, how the problem could be solved. Based on this problem, the students and faculty from both the universities developed a multimedia case study. The learning objectives of this case study are:

- Solving a problem using global engineering standards.
- Applying mechanics of acoustical design and acoustics engineering.
- Evaluating multiple alternative solutions to a design problem using a Decision Support System (DSS).

The case study provides background information about the companies and environments involved with the design and implementation of alternative solutions. The case study is available on the website (www.liteecases.com). The following multimedia tools are provided in the case study 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 reverberation time.
- Video interviews with company managers and engineers explaining the problem, alternative solutions considered, design issues, and the business ethics involved in this type of global engineering situation.
- An interactive sound simulator that demonstrates the effects of reverberation time when using the hall for different events such as conferences, rock concerts and automobile shows.
- Direct access to desired content through the categorized site map.

- Interactive DSS for use in evaluating design alternatives. The DSS that is provided in the case study is an evaluation matrix that provides eight criteria with which to evaluate the alternatives provided in the case study, along with appropriate weightings for each. Fig 2 shows a screenshot of the DSS.

DECISION SUPPORT SYSTEM MATRIX

CUSTOMER REQUIREMENTS	Importance Rating as per original design of hall	Alternative 1 - Fabric (used as a curtain)	Alternative 2 - Newtex	Alternative 3 - Anutone	Alternative 4 - Asona/Cellulose Spray	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	1	1	1	5	1.0	5	2	10	5.1%
Fire Safety	3	1	1	1	1	5	1.7	5	5	41.67	21.1%
Fixture Permanence	3	1	1	1	1	5	1.7	3	2	10	5.1%
Cost	3	1	1	1	1	3	1.0	3	4	12	6.1%
Performance	2	1	1	1	1	5	2.5	5	5	62.5	31.6%
Multipurpose Fixture Functionality	3	1	1	1	1	5	1.7	5	5	41.67	21.1%
Ease of Implementation	3	1	1	1	1	5	1.7	3	4	20	10.1%
Shipping Method	3	1	1	1	1	3	1.0	1	5	5	2.5%
									Total:	197.8	100.0%
OVERALL RATING OF EACH ALTERNATIVE		202.833	202.833	202.83	202.83						
Total Overall Rating			811.3333333								
RELATIVE OVERALL RATING OF EACH ALTERNATIVE AS PER DSS		**25.0%**	**25.0%**	**25.0%**	**25.0%**						

Read through the case study, analyze the information, and derive at a meaningful rating between 1 and 5 for each highlighted cell. Once you do this, the DSS computes an overall rating for each alternative. The alternative with the highest overall rating is the one that you prefer and the alternative with the lowest overall rating is the one you consider to be least important.

Fig 2. Screenshot of the Decision Support System (DSS)

In the classroom, students are expected to work in teams to provide their solution. The teams defending the various alternatives have to use both technical and non-technical (costs, risks, aesthetics) issues in their arguments. These issues are known to be serious requirements for an auditorium room and it must be remembered that, when an audience enters an auditorium, they have every right to expect comfort, safety, pleasant surroundings, good illumination, proper viewing, and good sound (Doelle, 1972).

4. Acoustic Fundamentals Used In the Case Study Relating To the Real-World Problem

The most important principles related to acoustical design of an auditorium include sound pressure level, absorption, noise reduction coefficient, and reverberation time (Beranek, 1992; Barron, 2010; Harris, 1991; Hassall & Zaveri, 1979). The following section explains in detail how the fundamentals of auditorium room acoustics are illustrated in the case study through this real-world problem. It also discusses the various alternatives provided to the student teams and how these fundamentals are used to assess their solution and to help them understand and appreciate the technical details behind the concepts. The students' grasp of the fundamentals is reflected in their decision support matrix.

4.1. Sound Pressure Level

The most common and important concept students come across in their daily lives is sound pressure levels (sound levels). The sound pressure levels are measured using a decibel scale. The decibel scale is also widely used in electronics, signals, and communication. The decibel (dB) is a logarithmic unit used to describe a ratio. The ratio may be power, sound pressure, voltage, intensity, or any of several other parameters (Hassall & Zaveri, 1979). Sound Pressure Level (SPL) is generally defined by

$$\text{SPL} = 20\, log_{10}\left(\frac{p_{rms}}{p_o}\right) \text{ decibels}$$

In this definition, p_{rms} denotes the 'root-mean-square' pressure and p_0 is an internationally standardized reference pressure; its value is 2×10^{-5} Pa, which corresponds roughly to the normal hearing threshold at 1000 Hz (Kuttruff, 2009). A linear number scale is normally used to define a logarithmic amplitude scale, there by compressing a wide range of amplitude values into a manageably small set of numbers. Because the scale represents logarithmic values, the numbers in the scale represent exponents rather than linear values.

4.1.1. *Application of sound levels in the case study*

Sound levels are proven to be a major factor in solving the problem in the polyvalent hall. The acousticians measured the sound level as the rock musicians practiced. The sound level recorded was 104 decibels (dB), well above the original design level of 94 dB. One reason the rock musicians experienced discomfort during practice was that the sound level was outside the design specifications. A concert at 104 dB has 10 times the intensity of a concert at 94 dB—a sizable difference. Given these considerations, an adjustment to the hall had to be designed in order to provide a good acoustic experience for both the performers and audience.

An important cultural issue that was partly responsible for the problem is that Indian music is played at a lower sound level, so the designers had simply not realized that rock concerts have an average sound level of 103 dB (Clark, 1991). This also shows the need for designers to understand the cultural issues associated with the location where the auditorium was to be used.

The acoustic consultant had to follow OSHA (Occupational Safety and Health Administration) standards when they proposed the solution for the polyvalent hall. He recommended not permitting performances to exceed a 104 – 105 dB sound level, as this exposure beyond an hour could permanently impair a listener's hearing, as per OSHA-specified thresholds. Using an example of a rock concert, something with which students are familiar, helps them relate to the idea of sound pressure levels in acoustics. This particular problem also helps demonstrate the issue of safety standards in design and engineering.

4.2. Absorption

Another important concept in the design of auditorium acoustics is total absorption. Acoustic absorption refers to the amount of sound energy absorbed by a given material. A mathematic term used to represent absorption is the **sound absorption coefficient** (Harris, 1991). The sound absorption coefficient of a material is the ratio of sound energy absorbed to the total incident sound energy on a unit area of the material and is denoted by α. In a material with α=0.5, 50% of the incident sound energy will be absorbed per unit area. All materials absorb sound to some extent; acoustical materials are those materials whose primary function is to absorb sound. Therefore, they absorb a relatively large fraction of the acoustical energy striking them. A number of different terms, including *sound absorption*, *room absorption* and *sabine absorption,* are explained in the case study. Its calculation is not straightforward; Kitumara et al., (2004) reported that the precise distribution of a large area of sound-absorbing material around a room can result in different absorption coefficients for that material, with the rear wall of an auditorium yielding a different absorption coefficient to the ceiling portion, for example. It has also been proven that audience absorption is proportional to the area over which it is distributed (Beranek, 1992).

4.2.1. *Application of absorption in the case study*

The glass panel of the VIP gallery at the rear wall of the polyvalent hall was also vibrating with high amplitude and listeners reported a lack of clarity and felt the sound to be distorted. Substantial portions of the back wall were bare and lacked any acoustical treatment. These areas reflected some portion of the sound energy back towards the source, creating additional reflected energy. The reflected energy detected was both loud and late-arriving, which resulted in multiple unwanted reflections.

A sound absorption coefficient test was performed at the Indian Institute of Technology Madras and the following information is provided in the case study, along with the test results below (Table I).

Sample: Fiber Glass Wall Covering the Liner (alternative 1)
Manufacturer: Saint-Gobain
Apparatus Used: Standing wave apparatus (Bruel & Kjaer, Type 4002)
Mounting Condition: Rigid backing

Table I. Readings from sound absorption test performed at IITM

Frequency(Hz)	125	250	500	1000	2000	4000
Sound Absorption Coefficient	0.1	0.15	0.2	0.27	0.3	0.38

Larsen & Toubro designed the polyvalent hall with moderate absorption acoustic materials that would result in acceptable sound levels in the hall for the anticipated uses. However, the rock concert caused acoustical problems because the hall was not originally designed to provide the necessary higher levels of absorption. The sound absorption test details can be compared to a video in the case study demonstrating the effect of absorption, and there is also a Power Point explaining basic facts about absorption to enable students to visualize how absorption works.

4.3. Noise Reduction Coefficient (NRC)

Another important principle students learn about acoustics is the use of the noise reduction coefficient. The NRC of a material is a single number representing the average value of the absorption coefficients of the material at frequencies of 250, 500, 1000, and 2000 Hz; this average is expressed to the *nearest multiple of 0.0523* (Hassall & Zaveri, 1979).

4.3.1. *Application of noise reduction coefficient in the case study*

To resolve the polyvalent hall's acoustical problem, the acoustician suggested a treatment using a fabric called Newtex (alternative 2) (Newtex-Architectural and Construction, 2015), which is primarily used as a fire retardant material but also acts as a good acoustic material by modifying the scattering properties of the surfaces covered. Newtex was tested and was found to absorb sound satisfactorily. The material exhibited an NRC of 0.22 when tested with a hard backing. Though the NRC value did not indicate the expected performance required for the polyvalent hall, the acoustic consultant recommended that Newtex would perform adequately fit was backed with two liner layers.

A cellulose spray (alternative 4), K-13 Asona, was suggested as another possible solution by the acoustic consultant. K-13 Asona spray can be easily applied to any wall or ceiling surface and at any thickness between 6 and 25 millimeters. K-13 Asona spray provides good sound absorption; at a thickness of 25 mm, the spray has a NRC value of 0.9. It can be applied flush with the surface intended for acoustical treatment, ensuring the aesthetics of the walls are not lost. However, the Asona spray would have to be ordered from the United States, possibly incurring a delivery delay. As they become familiar with these technical details and values about NRC relating to this real-world problem, the students are able to better visualize the concept and importance of NRC in auditorium design acoustics specially intended for rock concert performances.

4.4. Reverberation Time

In the work done by acousticians in concert halls, reverberation time plays a key role (Clark, 1991). Reverberation time is an important acoustic parameter for multi-purpose halls and can be described as the persistence or lingering of sound one hears within a room as the sound is continuously reflected by the room's boundaries and gradually dies away. Both speech and music are affected by reverberation; longer reverberation is more desirable for music, whereas shorter reverberation is more desirable for speech (Beranek, 1992; Barron, 2010). Each acoustic use of a hall has an optimum reverberation time associated with it (Beranek, 2003). Reverberation time can be adjusted for specific uses by careful placement of different absorptive materials.

4.4.1. *Application of reverberation time in the case study*

Students using the case study must have some familiarity with the concept of reverberation before they can tackle the problem. The case explains that during a visit to the polyvalent hall, the acoustic consultants found that the poor quality of sound experienced by the rock band arose mainly because of the high levels of reverberation within the hall. More absorption was needed to provide a better quality of sound for the rock concert, and the consultants felt that this could be resolved to a great extent by treating the rear wall, back wall and the ceiling of the hall with one of several proposed alternatives.

With limited time at his disposal, the acoustician suggested that a locally available fabric (alternative 1) with a surface density of 400-425 g/cm^2 be hung as curtains at specific locations on the wall surfaces as a stop-gap measure. This improved the situation and the rock concert took place the next day, February 11, 2005. However, the client wanted a more permanent resolution to the problem. The acoustic consultants therefore came up with three different permanent alternatives: Newtex (alternative 2), Anutone (alternative 3) and Cellulose spray (alternative 4).

The choice among these three alternatives involves an in-depth discussion of the importance of reverberation time in the acoustic design of the auditorium. Anutone is a wood/wool product made of wooden shavings and other fibrous and porous materials that is used extensively in many theatres and conference centers. The consultants determined that Anutone, if installed in the polyvalent hall, could reduce the reverberation time at low frequencies from its original measured value of 2 seconds to approximately 1.3 seconds. The effects of different reverberation levels are demonstrated in the case study using audio clips. To assess the general performance level at the polyvalent hall, the consultant performed three types of acoustic tests: (i) a cassette containing the sound of individual claps, (ii) a speech test and (iii) a music test. The claps simulate the impact of a short sound, clearly demonstrating the decay pattern produced when played through the existing fixed sound cluster system. The results of the frequency band analysis were:

Low frequency sound band: Decay rate ~ 30 dB
Mid and High frequency sound band: Decay rate ~33 dB

The acoustic consultant suggested some acoustic tuning and tweaking operations to obtain a more favorable reverberation field inside the hall. These are described in detail in the case study. An interactive reverberation time simulator (Fig 3) was developed for use in the case study to demonstrate the effect of design and materials on reverberation time. This real-world data, combined with the audio clips, gives students a better understanding of the concepts involved when considering reverberation times and levels.

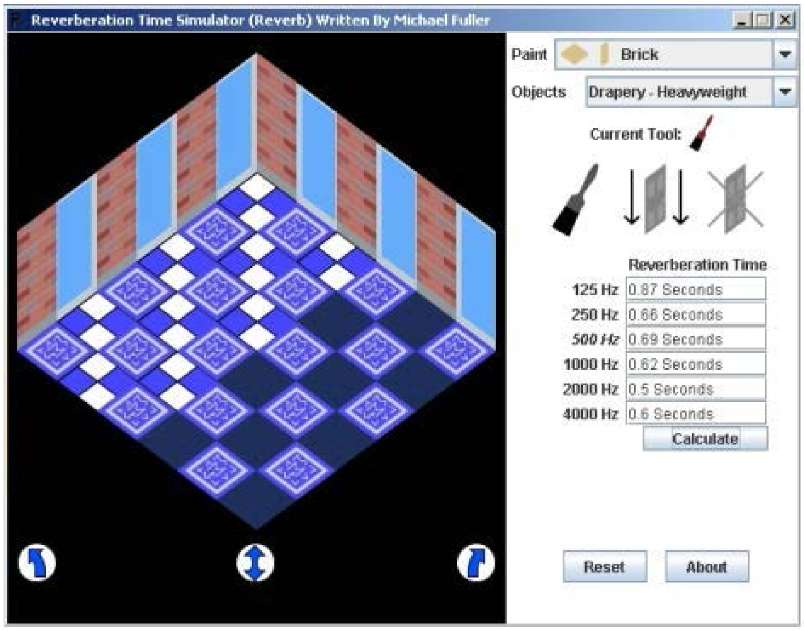

Fig 3: Interactive reverberation time simulator

Table II summarizes how the case study teaches the important fundamentals in acoustics.

Table II: Fundamentals of acoustics stressed in the case study

Fundamentals	Use of fundamentals in the case study
• Reverberation time	• Interactive reverberation simulator to demonstrate design and material effects on reverberation time. • Problem statement talks about higher reverberation times in the polyvalent hall. • Alternatives 1 & 3 and the review of the acoustics of rock music talk about reverberation levels. • Music audio clips are provided in the case study to demonstrate high, low and no reverberation.

• Noise Reduction Coefficient (NRC)	• Alternatives 2 & 4 talk about NRC levels. • Glossary explains the basics about NRC.
• Sound Pressure Level	• The problem statement and review of the acoustics of rock music bring out the issues concerning the sound pressure levels at the polyvalent hall. • The glossary defines decibel, decibel scale, sound pressure level.
• Absorption	• A video demonstrating absorption is included in the supplementary files of the case study. • The problem statement mentions the absorption levels in the hall. • Science of sound presentation explains sound absorption in air and different materials in detail.

5. Case Study Assignments and Implementation

Once the students have learned about the problems and the acoustic concepts through the case study, they are then expected to apply these concepts to assignments given to them. There is some flexibility in the case study, but the students in this study were divided into six teams to develop their solution to the problem assigned to them. Each student team had to come up with a presentation that discussed the main problem in the case study and defend their alternative, taking both technical and non-technical factors into consideration. The students defending an alternative had to use the DSS to compare their solution with the other alternatives. The teams performed the following tasks:

- Team 1: Defend the recommendation to implement the second alternative – Newtex
- Team 2: Defend the recommendation to implement the third alternative – Use of Anutone (wood/wool product)
- Team 3: Defend the recommendation to implement the fourth alternative – Use of Cellulose Spray (K-13)
- Team 4: Represent the team of Chuttur & Partners Limited and decide on the specific alternative that will be implemented. Provide both technical and non-technical reasons
- Team 5: Play the role of the CEO's of Chuttur and L&T and decide who will pay for the expenses. What are the ethical issues involved?
- Team 6: Play the role of the CEO of L&T and discuss the global issues that the company needs to consider in future projects? How do you prepare the Indian engineers for the future?

For this study, the case study was implemented in a multi-disciplinary classroom (mix of engineering and business students) at Auburn University with a predominantly Caucasian student body during the spring of 2014. It was also implemented in an engineering classroom at Hampton University, Virginia, that is an HBCU with the above mentioned student assignments.

6. Evaluation Results

Acoustic and engineering courses place a major emphasis on improving higher order cognitive skills, team-working skills, perceived learning and attitude toward learning acoustics in the process of solving real-world problems (Acoustical Engineering Course, 2015; Master Noise Control Engineering, 2015; Zsiga, 2015). In order to know whether a case study is effective or not, it must be evaluated in the correct manner. A common criticism when using new methodologies for teaching is that their effectiveness has not been adequately measured (Master Noise Control Engineering, 2015). A rigorous evaluation of these case studies is important in order to enhance students' knowledge base and improve educational practice, to increase the capacity of our undergraduates and graduates to conduct and communicate the results of their research, and to broaden participation and promote equity.

In the research reported by Fini (2010), two questionnaires were used to evaluate student feedback on the same case study. Each evaluation consisted of 23 bipolar descriptors (item). The students were asked to evaluate the effectiveness of the case study on a 5-point Likert scale, with 1 indicating an extremely negative rating and 5 an extremely positive rating. The questionnaire included items to measure the five constructs of higher order cognitive skills improvement: self-efficacy improvement, ease of learning subject matter, impact on team-working skills, and communication skills. The students completed the questionnaires, included their comments, and submitted them along with their term projects. Analysis of Variance (ANOVA) was conducted using a Statistical Package for the Social Sciences (SPSS). Fini's results (2010) revealed a significant improvement in higher-order cognitive domain of learning (HOC) when this case study was used in an engineering course at a state university.

Additional testing of the case study was done for a multi-disciplinary student classroom (30 students, 23% female, 10% minority) at Auburn University. In order to test the effectiveness of the Mauritius Auditorium Design case study in achieving the aforementioned outcomes, we implemented the case study as part of a multi-disciplinary course. The course enrolled a mix of engineering and business students at the junior - sophomore level. Data was collected from the following sources:

1. An evaluation questionnaire was used to collect responses from the students. The questionnaire included items to measure the five constructs of higher order cognitive skills, team-working skills, perceived learning, plus benefits, and positive attitude. The students were asked to evaluate the effectiveness of the case study on a 5-point Likert scale (with 1 indicating an extremely negative rating and 5 an extremely positive rating). The questions measuring the constructs are in Appendix A.
2. The second questionnaire collected the students' attitudes toward learning and studying. This questionnaire evaluated whether individual students used a deep learning approach or a surface learning approach to study and learn concepts (Biggs et al., 2001). The questions for this questionnaire are in Appendix B.
3. Open-ended survey responses.

Table III shows the descriptive statistics of the constructs for male and female, deep and surface learners, and Caucasian and minority students. The findings show that the means of all constructs are significantly higher than the neutral rating of 3.0. This indicates students' approval of the case study instructional mode.

Table III. Mean and standard deviations of the constructs as per the case study

Constructs	Higher Order Cognitive Skills	Team Working Skills	Perceived Learning	Plus Benefits	Positive Attitude	Average Pre-test scores	Average Post-test scores
	Mean (s.d.)	Mean (s.d)	Mean (s.d)	Mean (s.d)	Mean (s.d)	Mean (s.d)	Mean (s.d)
Male (N= 23)	3.67 (0.54)	3.61 (0.51)	3.53 (0.48)	3.42 (0.55)	3.60 (0.58)	8.30 (2.47)	8.69 (2.26)
Female (N = 6)	3.54 (0.66)	3.53 (0.67)	3.45 (0.67)	3.33 (0.45)	3.57 (0.57)	9.17 (2.78)	7.00 (2.82)
Deep Learners (N = 18)	3.71 (0.60)	3.71 (0.47)	3.66 (0.45)	3.44 (0.57)	3.65 (0.58)	8.83 (2.59)	8.61 (2.57)
Surface Learners (N = 11)	3.54 (0.48)	3.39 (0.60)	3.27 (0.56)	3.32 (0.44)	3.49 (0.57)	7.91 (2.38)	7.91 (2.26)
Caucasian (N = 26)	3.62 (0.58)	3.62 (0.53)	3.45 (0.52)	3.34 (0.52)	3.59 (0.57)	8.58 (2.55)	8.42 (2.15)
Minorities (N = 3)	3.92 (0.14)	3.39 (0.63)	4.00 (0.14)	3.89 (0.11)	3.60 (0.72)	7.67 (2.52)	7.67 (4.93)

These results also suggest that students with deep learning approaches have significantly higher mean ratings than those students who prefer the surface learning approach, indicating that the students with a deep learning approach to studying and learning like to work with multimedia case studies. The qualitative analysis (Fig 4) shows that 23 students found the use of case studies to be beneficial. Twenty-eight students indicated their preference for working in student groups/teams to solve the problems presented in the case study, while two students indicated a preference for working alone.

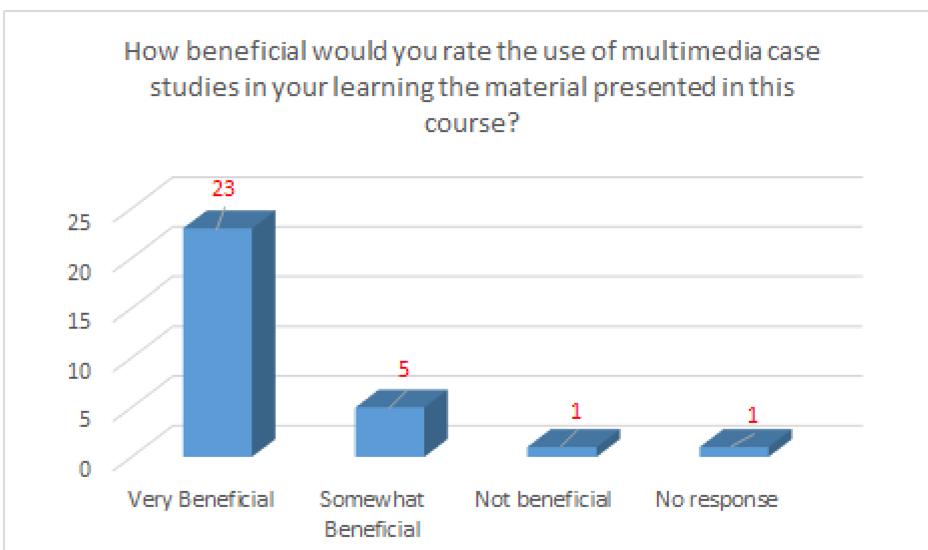

Fig 4. The number of students who benefitted from the case study

Fifteen students mentioned that they learned acoustic principles through the case study, eight that they learned ethics, and four that they learned decision-making after working on the case study.

6.1. Comments regarding the Mauritius Auditorium Design Case Study

The students described the case study as resourceful, interesting, and a good real-world application of acoustic concepts. One of the students commented, "The decision support matrix was most helpful in determining the characteristics of the alternatives." The majority of the students said they liked the teamwork aspect of the case study. Another student noted, "I learned different terms related to the science of acoustics (reverberation time and noise reduction coefficient) and I also learned the steps of decision making." Overall, the students had a positive response to the utilization of the case study in the class.

7. Implications For Educators

The research methodology discussed in the paper is a new way to teach fundamentals in auditorium room acoustics when compared to the traditional method of teaching. The combination of real-world data (rock concert sound levels, sound absorption test, reverberation levels) with audio (reverberation level) and video (absorption) clips helps students better visualize the concepts of auditorium room acoustics and relates the fundamentals of acoustics to a real-world acoustic problem through the case study. Since the case study also includes a number of different multimedia technologies, including Java applet, audio, video and Power Point, it ensures the students, as well as the faculty, are comfortable in using the case in a classroom environment. The case study evaluation confirms that this methodology has the potential to improve problem-solving skills, attitude toward learning acoustic concepts, and team working and communication skills.

8. Summary

The Mauritius auditorium design case study was developed in the summer of 2005 and has now been implemented several times in a classroom environment. This paper summarizes how the fundamentals of acoustics are illustrated in the case study using a real-world problem. The feedback from the students shows that the students were excited by the inclusion of case studies in the course, and that many commented on the ability of the case to provide more practical knowledge and experience about the subject. The evaluation results show that the case study improved students' higher-order cognitive skills, team-working skills, perceived learning and attitude toward learning acoustic concepts using multimedia case studies. The case study not only teaches students the fundamentals of acoustics but also gives them a real-world example to help them relate to what they have learned in class.

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Appendix A

Questions measuring the constructs for the study conducted at Auburn University

Constructs	*Questions to measure the constructs*
Higher order Cognitive Skills	• *The Mauritius Auditorium Design case study helped me learn how to inter-relate important topics and ideas.* • *The Mauritius Auditorium Design case study helped me learn how to identify various alternatives/solutions to a problem* • *The Mauritius Auditorium Design case study helped me improve my problem solving skills* • *The Mauritius Auditorium Design case study helped me learn how to sort relevant from irrelevant facts.*
Impact on Team Working Skills	• *The Mauritius Auditorium Design case study helped me improve my team-building and interpersonal skills* • *The Mauritius Auditorium Design case study improved consensus building skills among me and my classmates.* • *The sharing of ideas among classmates increased as a result of working on the Mauritius Auditorium Design case study.* • *The case study improved my ability to work in a team* • *The case study improved my ability to lead a team* • *The case study improved my ability to organize other people*
Perceived Learning	• *I learned new concepts in acoustics* • *I learned to identify central issues related to acoustics* • *I did additional reading on topics related to acoustics* • *I learned from other colleagues while working on the case study* • *I learned to value my colleagues' points of view* • *I did some thinking for myself about issues related to acoustics* • *The case study was helpful in learning difficult concepts*
Additional Benefits	• *The case study improved my presentation skills* • *The case study improved my writing skills* • *The case study improved my confidence in being able to apply engineering concepts to real-world situations* • *The case study improved my confidence in working in a company* • *The case study improved my confidence in creating my own engineering solutions* • *The case study improved my ability to complete tasks within deadline* • *The case study improved my ability to break large tasks into smaller tasks* • *The case study improved my ability to be innovative* • *I became more confident in expressing my ideas*

Positive Attitude towards Acoustics	• *From my experience in this case study I believe acoustics is irrelevant to my life.* • *This case study has increased my appreciation for field of acoustics.* • *From my case study experience, I think the field of acoustics is highly technical.* • *This case study has shown me that I can learn engineering.* • *Engineering skills learned in this case study will make me more employable.*

Appendix B

Questions to assess the attitudes toward studying and learning approaches

1. *I find that at times studying gives me a feeling of deep personal satisfaction.*
2. *I find that I have to do enough work on a topic so that I can form my own conclusions before I am satisfied.*
3. *My aim is to pass the course while doing as little work as possible.*
4. *I only study seriously what's given out in class or in the course outlines.*
5. *I feel that virtually any topic can be highly interesting once I get into it.*
6. *I find most new topics interesting and often spend extra time trying to obtain more information about them.*
7. *I do not find my course very interesting so I keep my work to the minimum.*
8. *I learn something's by rote, going over and over them until I know them by heart even if I do not understand them.*
9. *I find that studying academic topics can at times be as exciting as a good novel or movie.*
10. *I test myself on important topics until I understand them completely.*
11. *I find I can get by in most assessments by memorizing key sections rather than trying to understand them.*
12. *I generally restrict my study to what is specifically set as I think it is unnecessary to do anything extra.*
13. *I work hard at my studies because I find the material interesting.*
14. *I spend a lot of my free time finding out more about interesting topics which have been discussed in different classes.*
15. *I find it is not helpful to study topics in depth. It confuses and wastes time, when all you need is a passing acquaintance with topics.*
16. *I make a point of looking at most of the suggested readings that go with the lectures.*
17. *I see no point in learning material which is not likely to be in the examination.*
18. *I find the best way to pass examinations is to try to remember answers to likely questions.*