

Thesis Report

---

# Investigating Smart Classroom Acoustics Utilizing Computer Modeling

---

**Prepared by:**

**Mir Sabeer Hamid**  
Graduate Student & R. A. (ID # 200429)  
Architectural Engineering Dept.  
KFUPM, Dhahran (KSA)

**Principal Advisor:**

**Dr. Adel A. Abdou**  
Asst. Professor, Architectural Engineering Dept.  
KFUPM, Dhahran (KSA)

**Advising Committee Members:**

**Dr. Ismail M. Budaiwi**  
Associate Professor, Architectural Engineering Dept.  
KFUPM, Dhahran (KSA)

**Dr. Thamir Al-Rugaib**  
Asst. Professor, Architecture Dept.  
KFUPM, Dhahran (KSA)

---

## **THESIS ABSTRACT**

**STUDENTS NAME:** MIR SABEER HAMID  
**TITLE OF STUDY:** INVESTIGATING SMART CLASSROOM ACOUSTICS  
UTILIZING COMPUTER MODELING  
**MAJOR FIELD:** ARCHITECTURAL ENGINEERING  
**DATE OF DEGREE:** DECEMBER 2002

---

Optimum acoustical conditions in classrooms are essential for good listening conditions. Students with hearing difficulties and non-native listeners are greatly handicapped when the classroom acoustics are marginal or poor affecting the comprehension of delivered speech. Poor acoustical ambience affects teachers as well, talking over noisy classrooms can be exhausting to the teacher and to his or her willingness to dialogue with the students. With the evolution of new generation of classrooms referred to as 'Smart Classrooms', a large number of PC's and instructional equipment for interactive learning are integrated into the classroom. The instructional equipment generate noise that increments the existing background noise within a classroom affecting speech intelligibility (SI). The objective of this study is to investigate the impact of sound absorbing material treatment and the noise generated by classroom facilities and instructional equipment on SI. For better understanding of acoustical influencing parameters, measurements are carried out in conventional as well computer classrooms of King Fahd University of Petroleum and Minerals, Dhahran. Evaluation of measurements reveal the effects of surface finishing on sound behavior in classrooms and the Background Noise (BN) conditions existing in classrooms currently used for lecture delivery. Measuring the BN with equipment 'OFF' and 'ON' conditions assesses the effect of instructional equipment generated noise. A smart classroom model is simulated, varying the surface treatment to achieve the best overall configuration of sound absorption material characteristics and material placement. The derived best material configuration for a typical smart classroom is compared with the recommended classroom layouts to verify the effectiveness. Supported by acoustical measurements in existing conventional and computer-equipped classrooms, the acoustically optimized smart classroom is simulated under various BN levels and the impact of noise on acoustical indicators and SI is evaluated. The results clearly highlight the betterment in speech conditions with proper surface treatment at the same time, the detrimental effect of high noise environment on SI is noticed. Designers and educational establishments can use the outcome of this research as guidelines for retrofitting of existing classrooms as well as for new projects.

---

**MASTER OF SCIENCE DEGREE**

**KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS, DHAHRAN, SAUDI  
ARABIA**

**DECEMBER 2002**

## TABLE OF CONTENTS

List of Tables	.....	i
List of Figures	.....	iii
<b>1.0 Introduction</b>	.....	<b>1</b>
1.1 Important Issues	.....	2
1.2 Smart Classrooms	.....	3
1.3 Objectives	.....	5
1.4 Methodology	.....	5
1.5 Scope and Limitations	.....	8
<b>2.0 Literature Review</b>	.....	<b>9</b>
2.1 Background	.....	9
2.2 Speech Intelligibility Indicators	.....	10
2.3 Background Noise	.....	21
2.4 Comparison Speech Intelligibility Indicators	.....	24
2.5 Computer Classrooms for Active Learning	.....	26
2.6 Room Acoustics Modeling and Simulation Software	.....	33
2.7 Recent Studies	.....	53
<b>3.0 Acoustical Evaluation of Existing Classrooms</b>	.....	<b>67</b>
3.1 Introduction	.....	67
3.2 Classroom Selection Criteria and Characteristics	.....	68
3.3 Measurement Setup and Procedure	.....	73
3.4 Measurements and Analysis	.....	82
3.5 Analysis of Sample Classroom Measurement Results	.....	91

3.6	Trend Assessment	103
3.7	Effect of Instructional Equipment on Background Noise	105
3.8	Conclusion of Measurement Results	109
<b>4.0</b>	<b>Modeling a Typical Smart Classroom</b>	<b>113</b>
4.1	Introduction	113
4.2	The Classroom Model: Assumptions and Details	115
4.3	Initial Simulation Steps	120
4.4	STEP 1: Effect of Changing Sound Absorption Percentage on SI	124
4.5	STEP 2: Investigation of Sound Absorption Material Placement on Classroom Ceiling	131
4.6	STEP 3: Investigation of Sound Absorption Material Placement on Classroom Walls	137
4.7	STEP 4: Comparison of Sound Absorption Material Placement Alternatives	143
4.8	STEP 5: The Effect of Background Noise on Speech Intelligibility	150
<b>5.0</b>	<b>Conclusions and Recommendations</b>	<b>154</b>
5.1	Summary and Conclusion	154
5.2	Recommendations	168
5.3	Future Study	172
	References	
	Appendix A	
	Appendix B	
	Appendix C	