BUILDING PHYSICS and ENERGY SIMULATION WORKSHOP

27-30 January 2010
at Indian Institute of Technology, Roorkee

Organized by
USAID ECO-III Project, in association with
Vienna University of Technology, Austria
Bureau of Energy Efficiency, and
Indian Institute of Technology, Roorkee

This publication was made possible through support provided by the U.S. Agency for International Development, under the terms of Award No. 386C-00-06-00153-00. The opinions expressed herein are those of International Recourses Group and do not necessarily reflect the views of the U.S. Agency for International Development or the United State Government.

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FROM THE AMERICAN PEOPLE

TU WIEN TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

ENERGY IS LIFE
BEE
CONSERVE IT

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USAID ECO-III Project

Educational Curriculum Enhancement Program

The Energy Conservation and Commercialization (ECO) Program was signed between the Government of India (GOI) and USAID in January 2000 under a bilateral agreement with the objective to enhance commercial viability and performance of Indian energy sector and promote utilization of clean and energy-efficient technologies in the sector. USAID's ECO program has a long history of association with Bureau of Energy Efficiency (BEE) on Energy Conservation Building Code (ECBC) starting with development of ECBC and continuing with its implementation under the third phase of the ECO program.

BEE and USAID ECO-III project have initiated a unique program to develop capacity of architects, engineers, and building energy efficiency professionals, as well as architecture and engineering students to help with implementation of Energy Conservation Building Code (ECBC) and equip them with the knowledge and technical skills to design sustainable buildings and habitats. This effort hopes to empower the architecture and engineering students by providing them access to quality technical reference material and equipping them with fundamental principles of building energy efficiency, and giving access to state of the art energy simulation tools so that they are well prepared to take on the sustainability challenges that India is already facing in the building design and construction sector. The objective of this initiative is to make India a global and intellectual leader in the field of building physics and energy simulation by 2015.

At the beginning of the project, the ECO-III team conducted an Architectural Curriculum Survey focusing on the Environmental Design course work. The feedback received helped the ECO-III team in identifying the academic institutes that are ECO-III project partners under this initiative. With the support of BEE and USAID, ECO-III Project procured and distributed the "*E Source Technology Atlas Series*" Books (on Lighting, Cooling, Heating, Appliances, and Drive Power) and "*Window Systems for High Performance Buildings*", along with DesignBuilder energy simulation software to all the institutional partners.

USAID ECO-III project in collaboration with Asia Pacific Partnership (APP) on Clean Development and Climate and National Institute of Advanced Studies in Architecture (NIASA) at Pune organized a "Train the Trainer" Workshop in January 2009 where faculty members from India's leading architectural and engineering colleges participated. The objective was to provide detailed guidance on the topic of Building Physics and Energy Simulation and how an awareness of the fundamental concepts taught in these two courses can help in both understanding ECBC and designing ECBC-compliant buildings. This four-day workshop at Indian Institute of Technology, Roorkee, has been organized as a follow-up of the workshop at Pune.

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Acknowledgement

This document was produced for review by the United States Agency for International Development (USAID). It was prepared by International Resources Group for the Energy Conservation and Commercialization Project.

SUMMARY

A four-day regional workshop was organized at the Indian Institute of Technology, Roorkee, between 27-30 January 2010 on Building Physics and Energy Simulation. The event was sponsored by the USAID ECO-III Project in association with Vienna University of Technology, Austria, and Bureau of Energy Efficiency, and hosted by IIT Roorkee.

The objective of the workshop was to introduce the basics of building physics and energy simulation to the academic community consisting of teachers and future architects (students). However, the larger aim of the event was to make them aware of the need to incorporate subjects related to the fundamentals of buildings physics, climatology, passive design, and energy efficiency and sustainability within the architectural curriculum. It has been widely accepted that the architecture and its profession are experiencing a paradigm shift where the issues of sustainable environment, resource conservation and energy efficiency have assumed paramount importance. In order to sustain life in a holistic way, it is important to address these issues with a sense of urgency.

This workshop and more such as these are aimed at bridging the gap that exists between the needs of the profession/society and the existing capacity for implementing energy efficiency on a large scale. The introduction to building physics gives a general overview of the behavior of a building and understanding its dependency on the outdoor environmental conditions. It introduces concepts like building envelop elements and their role in heat transfer, basics of daylight and its integration with artificial lighting, principles of acoustics, and all the related terminology. The second part of the workshop deals with energy simulation process and software as well as the strengths and limitations of such calculations. The idea behind coupling building physics and energy simulation is to emphasize the importance of the former towards understanding the latter. It is important that a prior understanding of the basics of building physics is in place before these simulation tools can be used in a sensible and appropriate manner.

WORKSHOP STRUCTURE

The workshop was divided into two parts: Building Physics and Energy Simulation (Please see the detailed schedule in Appendix A). A component of introduction to Energy Conservation Building Code (ECBC) was included as part of the first two days to emphasize the importance of energy simulation tools for ECBC compliance if one goes for the Whole Building Performance Compliance approach. On the first day, a questionnaire based on building physics principles was circulated to be filled-in by the participants to gauge the level of understanding of the subject and to, thereby, put forth relevant information for optimal assimilation of knowledge and information. The questionnaire focused on subjects like thermal behavior, lighting, acoustics, and research methods (Please see Appendix C for detailed questionnaire and results).

INSTRUCTORS

A combination of international and Indian faculty members and trainers provided their expertise towards the "Train the Trainer" sessions. They are:

- Dr. Ardeshir Mahdavi, Director and University Professor, Department of Building Physics and Building Ecology, Vienna University of Technology, Austria
- Dr. Kristina Orehounig, Department of Building Physics and Building Ecology, Vienna University of Technology, Austria
- Dr. Satish Kumar, Chief of Party, USAID ECO-III project
- Ms. Sanyogita Manu, Energy Efficiency Research Associate, USAID ECO-III Project

PARTICIPATION

The workshop at Roorkee turned out to have an overwhelming participation. Seventy-five students from nine architecture colleges from Northern India and 10 faculty members as well as students and faculty members from Architecture, Civil, Mechanical, and Electrical department and scientists from the Central Building Research Institute (CBRI, Roorkee) participated in the workshop. This interesting mix of backgrounds in terms of the variation in fields as well as levels of expertise/interest was one of the most important features/accomplishments of the workshop. (See the list of participants in Appendix B for details).

Each institute was requested to send both students and faculty members for attending the workshop. The boarding and lodging of all participants was taken care of by the USAID ECO-III Project and IIT, Roorkee. Course material provided to each participant included the following ECO-III Project Publications:

1. Energy Assessment Guide for Commercial Buildings
2. Energy Conservation Building Code User Guide
3. ECBC Tip Sheet Building Envelope
4. ECBC Tip Sheet-Building Lighting Design
5. ECBC Tip Sheet-Energy Simulation
6. ECBC Tip Sheet-HVAC System

At the end of the workshop, each participant was awarded a Certificate of Participation.

EVALUATION

Towards the completion of the workshop, an evaluation questionnaire was distributed among the participants to provide feedback on the following categories:

- Training Workshop
- Instructors
- Training Content
- Audio Visual Material
- Overall satisfaction

Generally, it was observed that most of the participants thought the workshop was very useful in terms of providing relevant information and enhancing their knowledge as well as skills. A certain degree of comfort level with both the basics of building physics and the simulation tool had developed by the end of the event. A more detailed analysis of the Evaluation results is given in Appendix D and E.

Some specific comments included:

- Good instruction methods, literature and exercises
- Good variety of topics
- Lack of promotion/awareness of such events
- Need for more such workshops
- Importance of hands-on training sessions

Few detailed testimonials from some of the attendees, both teachers and students are given in Appendix F.

PRESS RELEASE

The event was widely covered by most of the local newspapers of the region because of its huge success. The translated version of the content in one of the articles is given below.

IIT Roorkee Holds a Workshop on Energy Conservation Building Code and Energy Simulation

The Indian Institute of Technology Roorkee, with assistance from USAID funded ECO-III project, Bureau of Energy Efficiency, and Vienna Institute of Technology, is conducting a four-day workshop to provide an intensive training programme on the fundamental principles behind the design of energy-efficient buildings. The invited 90 participants include the students of B.Arch. 4th and 5th year & faculty members from Eleven architecture & engineering institutes. These are AMU Aligarh, GNDU Amritsar, GZET Bhatinda, CCA Chandigarh, DIT and HNV Dehradun, NIT Hamirpur, MNIT Jaipur, BBD and Faculty of Architecture Lucknow and IIT Roorkee, all from North India. The key objective of the workshop is capacity building, ensuring that the participating institutes incorporate these processes as an integral part of their curriculum and thereby enabling designers to develop energy efficient buildings.

Dr. Ardeshir Mahdavi and Dr. Kristina Orehounig from Vienna Institute of Technology along with Dr. Satish Kumar, Head of the ECO-III Project will be teaching the course. The workshop is being organized under the ongoing USAID supported ECO-III Project, which has undertaken a long-term capacity building programme focusing on architecture and engineering students to prepare them to design Green and Sustainable buildings. The workshop will teach the fundamentals of Building Physics and Energy Simulation which will assist the students in designing Energy Conservation Building Code compliant and energy-efficient buildings.

Dr. P.S. Chani, Assistant Professor at the Department of Architecture at IIT Roorkee, who played a key role in conceiving and organizing the programme, said that special training workshops make both the students and faculty members aware about the importance of computational tools that can perform sophisticated energy analysis. Bureau of Energy Efficiency and USAID should be lauded for their efforts to bring in state of the art energy analysis tools like DesignBuilder and EnergyPlus that would allow the students to enhance their skills and become environmentally conscious architects.

FUTURE STEPS

During the workshop, many colleges and schools of architecture approached the ECO-III team and requested them to expand the program so that their institutes can also become partners of BEE and USAID. The ECO-III Project is now undertaking the exercise of following up with the participant institutes along with exploring the possibility of other architecture colleges interested in becoming one of the ECO-III Partner institutes. The institutes joining the group would be receiving the *"E Source Technology Atlas Series*" Books (on Lighting, Cooling, Heating, Appliances, and Drive Power) and "*Window Systems for High Performance Buildings*" along with

the DesignBuilder software which is a building energy simulation tool. The Project is also trying to conduct more workshops and training sessions in different colleges based on the feedback received from the participants.

ECO-III project is also chalking up plans on the next set of activities it will undertake to take advantage of the partnerships and relationships that have already been developed. Some activities that are currently being contemplated are listed below:

- In partnership with the BEE, help design an award for best architectural thesis incorporating energy analysis through energy simulation;
- Help develop two new educational courses on Building Science for undergraduate programs and Energy Modelling for post-graduate programs;
- Help develop an Environmental Design Studio Problem that can be pilot tested to integrate the theoretical concepts into the design process;
- Develop web-based teaching curriculum, text books, etc. that can be used as standard teaching material by academic institutions, in partnership with internationally renowned universities (Technical University of Vienna, Arizona State University, for example), and help develop diagnostic capabilities of the institutes (may require additional funding from other sources, e.g. BEE, REEEP, etc).
- Depending on additional resources, consider the possibility of expanding the program to those institutes who have made good progress without being our formal partners.

APPENDIXES

Appendix A: WORKSHOP AGENDA

Day 1: January 27, 2010		
0900 - 0945	Introduction and Objectives of the Workshop	Dr. Chani and Dr. Satish Kumar
0945 - 1000	Tea Break	
1000 - 1030	Questionnaire	
1030 - 1200	Lecture 1: Introduction to building physics	Prof. A. Mahdavi
1200 - 1215	Break	
1215 - 1315	Lecture 2: Fundamentals of thermal performance of buildings	Prof. A. Mahdavi
1315 - 1430	Lunch Break	
1430 - 1530	Lecture 3: Fundamentals of thermal performance of buildings	Prof. A. Mahdavi
1530 - 1600	Q/A Session followed by discussion	
1600 - 1630	Tea Break	
1630 - 1730	Lecture 4: Building energy Scenario and Energy Conservation Building Code	Dr. Satish Kumar

Day 2: January 28, 2010		
0900 - 0930	Day 1 recap, Discussion of workshop reference material and Overview of Day 2	Dr. Chani and Dr. Satish Kumar
0930 - 1030	Lecture 5: Fundamentals of lighting performance of buildings	Prof. A. Mahdavi
1030 - 1100	Tea Break	
1100 - 1200	Lecture 6: Prof. A. Mahdavi, Fundamentals of lighting performance of buildings	Prof. A. Mahdavi
1200 - 1300	Lecture 7: Energy Conservation Building Code (in detail)	Dr. Satish Kumar
1300 - 1430	Lunch Break	
1430 - 1630	Lecture 8: Introduction to scientific research design and methods	Prof. A. Mahdavi
1630 - 1700	Tea Break	
1700 - 1800	Documentary Screening	

Day 3: January 29, 2010		
0930 - 1100	Lecture 9: Overview of Simulation Tools and DesignBuilder	Dr. Kristina Orehounig and Sanyogita Manu
1100 - 1130	Tea Break	
1130 - 1300	Lecture 10: Overview of Simulation Tools and DesignBuilder	Dr. Kristina Orehounig and Sanyogita Manu
1300 - 1430	Lunch Break	
1430 - 1630	Lecture 11: Creating building models in DesignBuilder (Geometry, Zones, Construction)	Dr. Kristina Orehounig and Sanyogita Manu
1630 - 1700	Tea Break	
1700 - 1800	Lecture 12: Creating building models in DesignBuilder (Schedules, activities)	Dr. Kristina Orehounig and Sanyogita Manu

Day 4: January 30, 2010		
0930 - 1100	Lecture 13: Simulation runs in DesignBuilder	Dr. Kristina Orehounig and Sanyogita Manu
1100 - 1130	Tea Break	
1130 - 1300	Lecture 14: Obtaining and interpreting simulation results	Dr. Kristina Orehounig and Sanyogita Manu
1300 - 1430	Lunch Break	
1430 - 1600	Lecture 15: Advanced applications in thermal performance simulation	Dr. Kristina Orehounig and Sanyogita Manu
1600 - 1630	Tea Break	
1630 - 1800	Concluding session, QA, and Next Steps	Moderator: Prof. Chani

Appendix B: LIST OF PARTICIPANTS

Faculty of Physical Planning & Architecture, Guru Nanak Dev University, Amritsar, Punjab

1. Dr. Sandeep Dua, Professor
2. Ms. Kirti Ahluwalia, B. Arch. V
3. Ms. Gurnoor Kaur, B. Arch. V
4. Mr. Thakur Udayveer Singh, B. Arch. V
5. Mr. Amanpreet Singh, B. Arch. IV
6. Mr. Rahul, B. Arch. IV
7. Mr. Guneet Singh, B. Arch. IV
8. Mr. Karandeep Grover, B. Arch. IV
9. Mr. Manmeet Singh Tuli, B. Arch. V
10. Mr. Pranesh Mittal, B. Arch. V

School of Architecture, Babu Banarasi Das National Institute of Technology & Management, UP Technical University, Lucknow, Uttar Pradesh

11. Mr. Mohit Kumar Agrawal, Professor
12. Mr. Prashant Chaturvedi, B. Arch. V
13. Ms. Tulika, B. Arch. V
14. Ms. Vartika Srivastava, B. Arch. V
15. Mr. Shaurabh Chaurasia, B. Arch. IV

Chandigarh College of Architecture, Punjab University, Chandigarh, Punjab

16. Ms. Sumedha Amod Gupta, Professor
17. Mr. Ravindra S. Gill, Professor

Faculty of Architecture, Dehradun Institute of Technology, Uttaranchal Technical University, Dehradun, Uttarakhand

18. Mr. Jitendra Kr. Sarohi, Professor
19. Ms. Kriti Bhalla, B. Arch. IV
20. Ms. Priti Saini, B. Arch. IV
21. Mr. Udit Singh, B. Arch. IV
22. Mr. Inder Dev Sharma, B. Arch. IV
23. Mr. Bhaskar Kandpal, B. Arch. V

Faculty of Architecture, Zakir Hussain College of Engineering & Technology, Aligarh Muslim University, Aligarh, Uttar Pradesh

24. Mr. S. M. Noman Tariq, Professor
25. Mr. Shafiq Ur Rahman, B. Arch. IV
26. Mr. Udit Gaurav, B. Arch. IV
27. Ms. Shikha Singh, B. Arch. IV
28. Ms. Garima Varshney, B. Arch. IV
29. Mr. Divya Kumar Garg, B. Arch. IV
30. Ms. Rashmi Sharma, B. Arch. IV

Faculty of Architecture, Himgiri Nabh Vishwavidyalaya, Dehradun, Uttarakhand

31. Mr. Rachit, Professor
32. Ms. Meenakshi, B.Arch. IV
33. Mr. Jitendra Singh, B.Arch. IV
34. Mr. Shamshad Khan, B.Arch. IV
35. Mr. Shashank Dikshit, B.Arch. IV
36. Mr. Noman, B.Arch. IV

School of Architecture, Giani Zail Singh College of Engineering &Technology, Punjab Technical University, Bhatinda, Punjab

37. Mr. Avinash Singh, Professor
38. Ms. Ashima Mittal, B. Arch. V
39. Mr. Wasif, B. Arch. V
40. Mr. Mugeesh Alam, B. Arch. IV
41. Mr. Goutam Kumar, B. Arch. IV

Malviya National Institute of Technology, Jaipur, Rajasthan

42. Mr. Ankur Tulsyan, B. Arch. IV
43. Mr. Srijan Didwania, B. Arch. IV

National Institute of Technology, Hamirpur, Himachal Pradesh

44. Ms. Heena Hussain, B. Arch. IV
45. Ms. Nipun Behl, B. Arch. IV
46. Mr. Kuldhir Singh, B. Arch. IV
47. Mr. Yogender Pal Singh, B. Arch. IV
48. Mr. Shashi Kant Singh, B. Arch. IV

Faculty of Architecture, U.P. Technical University, Lucknow, Uttar Pradesh

49. Mr. Zia ul Haq, B. Arch. IV
50. Mr. Anjaneya Sharma, B. Arch. IV
51. Mr. Vishvanath Ghosh, B. Arch. IV
52. Mr. Satish Kumar, B. Arch. IV
53. Mr. Ankur Joshi, B. Arch. IV
54. Mr. Yogender Pal Singh, B. Arch. IV
55. Mr. Pankaj Gangwar, B. Arch. IV

Indian Institute of Technology, Roorkee

56. Mr. D. P. Singh, Ph.D. candidate
57. Mr. Ashok Kumar, Ph.D. candidate
58. Mr. Sriniwas V., Ph.D. candidate
59. Mr. Abdul Raheem, Ph.D. candidate
60. Mr. H.C Arora, Ph.D. candidate
61. Mr. Pawan Kumar, Ph.D. candidate
62. Ms. Aanchal Sharma, Ph.D. candidate
63. Mr. Kishore Kulkarni, Ph.D. candidate
64. Mr. Navneet Menott, Ph.D. candidate
65. Ms. Aiswarya S. Baburaj, M.Arch. I
66. Mr. Dattatreya O.V., M.Arch. I
67. Ms. Divyanshi Chopra, M.Arch. I
68. Mr. Nabeel Kamarudheen, M.Arch. I
69. Mr. Nikhil Sisdharan, M.Arch. I
70. Mr. S. Raghunath, M.Arch. I
71. Mr. Saurab Sharma, M.Arch. I
72. Ms. Sreenita Mukherjee, M.Arch. I
73. Mr. Udayan, M.Arch. I
74. Ms. Shailza Singh, M.Arch. II
75. Mr. Palash Deolankar, M.Arch. II
76. Ms. Pushpla Gupta, M.Arch II
77. Mr. Rahul Majumdar, M.U.R.P. I
78. Ms. Prajakta B, M.U.R.P. I
79. Ms. Debapriya Guha, M.U.R.P. I
80. Ms. Charuta T., M.U.R.P. I
81. Ms. Sweta Kotpalliwar, M.U.R.P. I
82. Ms. Aruna Venkatraman, M.U.R.P. I
83. Mr. Amit R. Goray, M.Tech, Civil Engineering
84. Mr. H Raghuvanshi, M.Tech, Civil Engineering
85. Mr. Sanjay Pal
86. Mr. Akshay Kr. Suman, B.Arch IV
87. Mr. Varun Singh, B.Arch IV
88. Mr. Naman Srivastava, B.Arch IV
89. Mr. Rahul Sharma, B.Arch IV
90. Mr. Hrishi Raj Agarwalla B.Arch IV
91. Mr. Shubham Agarwal, B.Tech II, Civil Engineering
92. Mr. Sandeep Kr. Singh, B.Tech II, Civil Engineering
93. Mr. Rohit Kumar, B.Tech II, Civil Engineering
94. Mr. Shashank Shekar, B.Tech II, Civil Engineering
95. Mr. Vidish Iyar, B.Tech II, Civil Engineering
96. Mr. Prashant Kumar, B.Tech II, Civil Engineering

Appendix C: BUILDING PHYSICS QUESTIONNAIRE[1]

(Please cross only one answer)

Name: _____
Score: _____

1. Have you had any previous courses in building physics? (thermal, acoustical, visual aspects of building performance)
- No
- Just one course
- More than one course

2. Have you used an energy performance simulation tool before?
- No
- Yes

I used: _____

3. Which of the following is CORRECT?
- Mechanical energy is the sum of kinetic and thermal energy
- Kinetic energy is mass times acceleration times 2
- The unit of work is Newtons times meter
- Potential energy is the sum of mass, earth acceleration, and gravity

4. Which of the following is INCORRECT?
- Temperature differences should be expressed in Kelvin
- Absolute zero is roughly -273 K
- The unit of pressure is Newton per meter squared
- Absolute zero is roughly -273 °C

5. What does the first law of thermodynamics imply?
- In a closed system, energy is spontaneously transferred from a high-temperature
- region to a low-temperature region
- In every mechanical process, a fraction of energy is destroyed due to friction
- Energy transfer per units of time represents a system's capacity to perform work
- Energy cannot be destroyed, but only transformed from one form to another

6. What does the second law of thermodynamics imply?
- In a closed system, energy is spontaneously transferred from a high-temperature region to a low-temperature region
- In every mechanical process, a fraction of energy is destroyed due to friction
- Energy transfer per units of time represents a system's capacity to perform work
- Energy cannot be destroyed, but only transformed from one form to another

7. In the course of thermodynamic processes in a closed system,
- Entropy decreases, while exergy increases
- Entropy increases, while exergy is depleted
- Entropy and exergy increase, while enthalpy decreases
- Exergy and enthalpy increase, while entropy remains constant

8. Which of the following is correct?
- Convection occurs in vacuum, whereas conduction occurs in fluids
- Radiation occurs in vacuum, whereas convection occurs in solid media
- Convection occurs in gases, conduction in liquids
- Conduction and convection require a material medium, but not radiation

[1] *Prepared by Department of Building Physics and Building Ecology, Vienna University of Technology, Austria*

9. Thermal conductivity of a material
- is expressed in units of $W.m^{-2}.K^{-1}$
- is expressed in units of $J.s^{-1}.m^{-2}.oC^{-1}$
- is expressed in units of $W.m^{-1}.K^{-1}$
- is expressed in units of $J.s^{-1}.m^{-1}.oC^{-1}$

10. A black body
- radiates as much energy as it reflects
- radiates with the maximum intensity that a body of its temperature can possibly do
- has a emissivity of zero and a reflectance of 1
- emits energy with the same intensity over the whole spectrum of electromagnetic radiation

11. Four containers (A: polished metal, B: matt metal, C: matt black, D: polished black) containing warm water of the same temperature are placed on a table. After 10 minutes, which one will be the warmest?
- A
- B
- C
- D

12. What is the meaning of PMV and PPD?
- These are indicators of air quality in a room according to the adaptive theory of air exchange rates
- These are indicators of thermal comfort according to the conventional thermal comfort theory
- PMV denotes predicted mean velocity, PPD denotes predicted percentage of decay
- These are abbreviation for statistical measures of room acoustics

13. U-value
- denotes the thermal transmittance of building components (walls, roofs, windows, etc.)
- denotes a utility function for convective heat transfer
- denotes the energy transfer difference between one-dimensional (planar building components) and multi-dimensional (thermal bridges) heat transfer
- denotes a measure for area-related heating and cooling loads of buildings

14. What is the difference between irradiance and illuminance?
- Irradiance is measured in lx (lux), whereas Illuminance is measured in $W.m^{-2}$
- Irradiance is measured in $W.m^{-2}$ whereas Illuminance is measured in lx (lux)
- Irradiance considers the spectral sensitivity of human eye, whereas illuminance is a purely physical entity
- Illuminance is a logarithmic expression for irradiance

15. Daylight factor
- relates to the energy efficiency of OLED light sources
- denotes the ratio of external to internal illuminance levels
- denotes the energy transfer difference between one-dimensional (planar building components) and multi-dimensional (thermal bridges) heat transfer
- denotes the ratio of internal to external illuminance levels

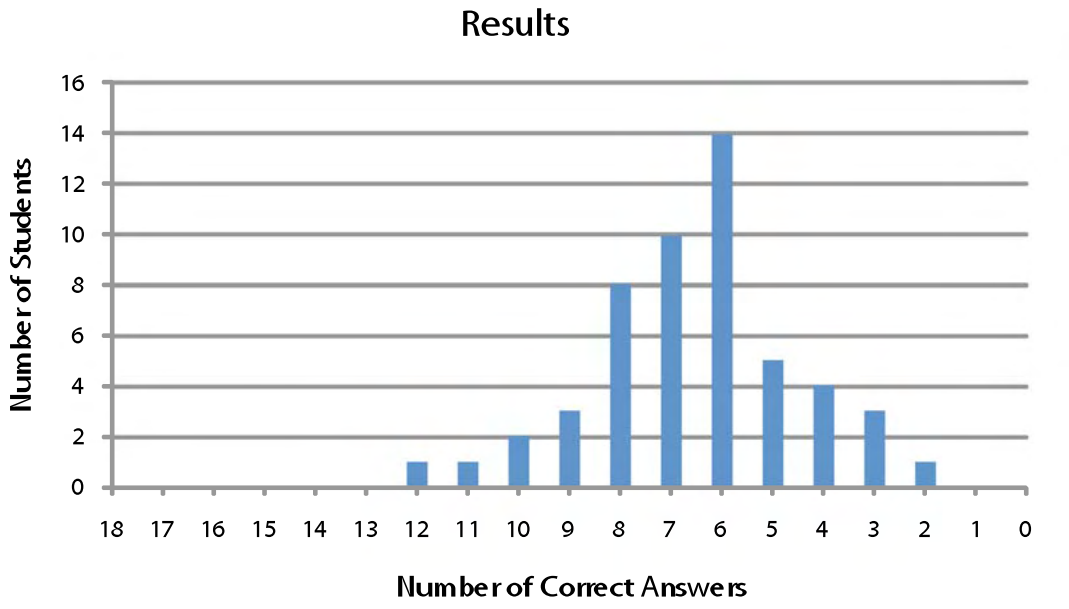
16. Glare
- occurs due to low contrast difference between task and background denotes the thermal transmittance of building components (walls, roofs, windows, etc.)
- is a result of the presence of high luminance sources in the visual field denotes a utility function for convective heat transfer
- is an indicator of the radiation transfer through glazing systems
- denotes a measure for area-related heating and cooling loads of buildings

17. Reverberation time
- denotes the time for the sound energy to drop 60 dB in a room after the sound source has been switched off
- denotes the temporal difference between the arrival of direct and reflected sound energy in a room
- is approximately 340 m.s-1 for air as a medium
- is a measure of sound transmission between two adjacent spaces

18. Which of the following statements is correct?
- Sound pressure is measured in dB (decibel), whereas sound intensity is measured in Pa
- Sound power level denotes the sound intensity level measured at a reference distance of 10 meters from a sound source
- According to inverse square law, the sound level is dropped 8 decibels, every time the distance to a sound source is doubled
- Sound pressure level is measured in dB (decibel), where as sound pressure is measured in Pa

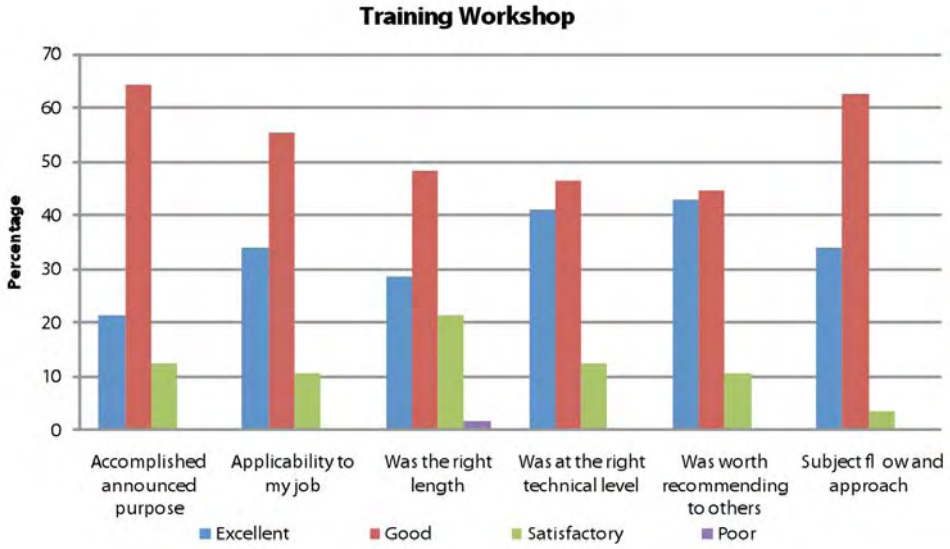
19. What is the difference between single-blind and double-blind experiments?
- Single-blind experiments are conducted in hard sciences. Double-blind experiments are conducted in medical research.
- In single-blind experiments subjects do not know to which group (experimental/control) they belong to. In double-blind experiments neither the subjects nor the experimenters know of the composition of the experimental and control groups.
- Single-blind experiments are conducted with people who have lost one of their eyes, while double-blind experiments are done with people who have lost both of their eyes.
- Single-blind experiments involve matching in experimental groups; double-blind experiments involve matching in control groups.

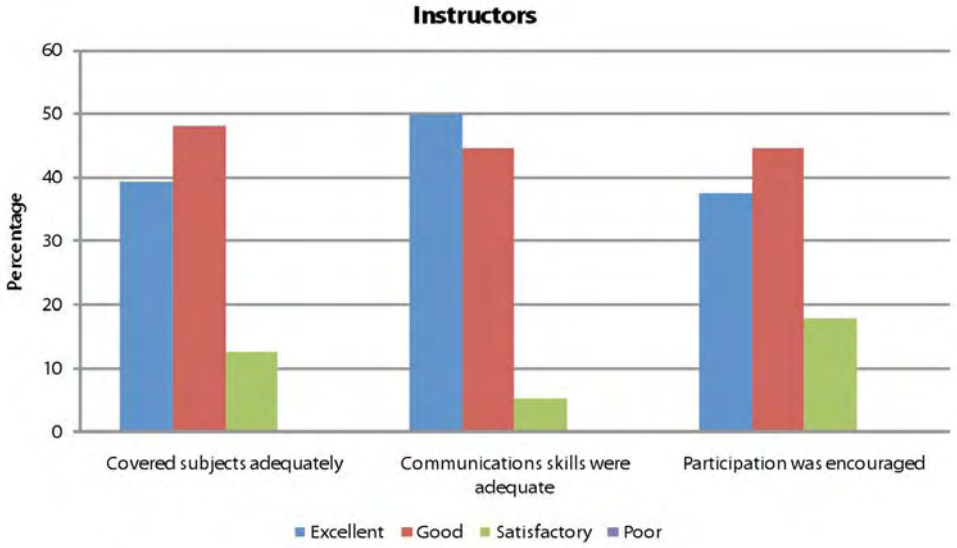
20. What does null-hypothesis mean?
- It means the results of an experiment must be disregarded (nullified) due to mistakes and fallacies.
- It means that the initial conditions in the experiment must be critically observed.
- It suggests that an implied effect of a suspected cause does not exist in the population
- It means that a hypothesis must be rejected before it can be accepted.

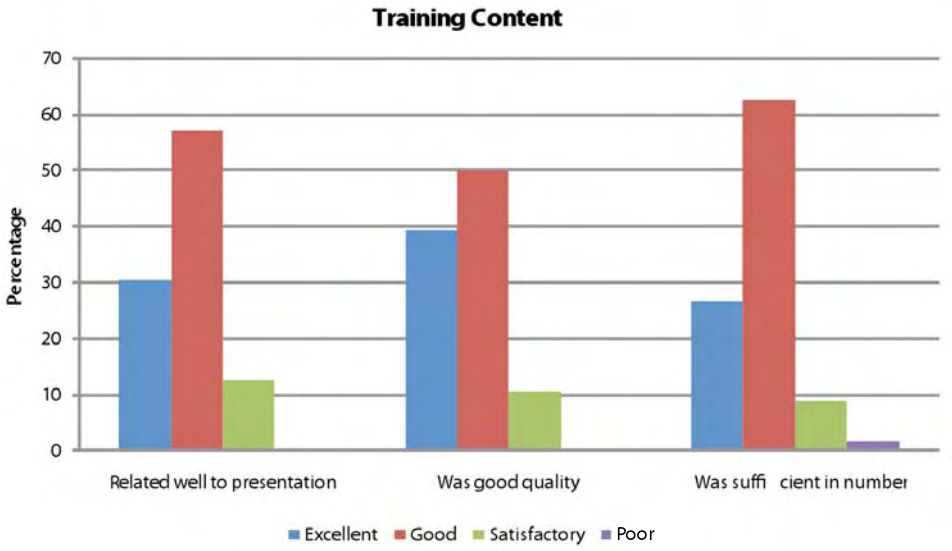


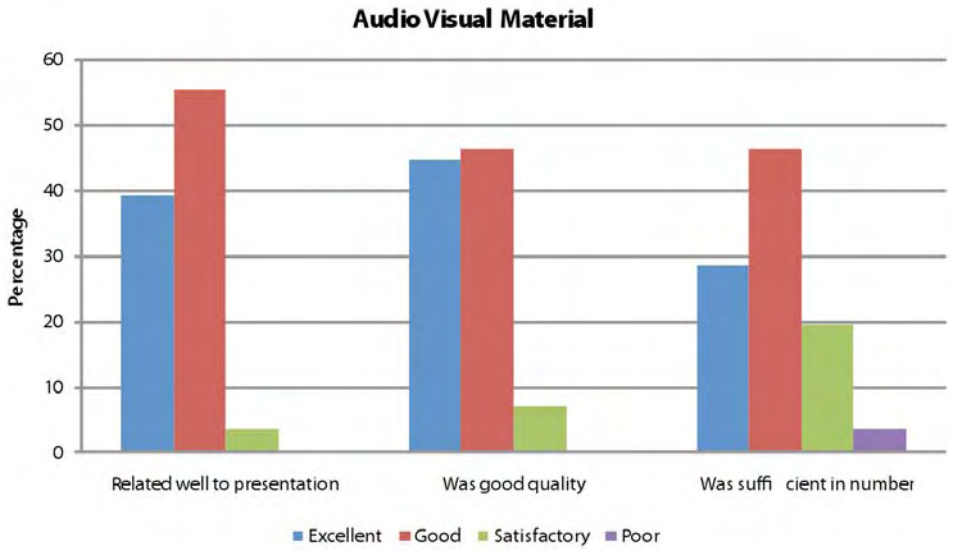
52 Questionaires, 18 points maximum

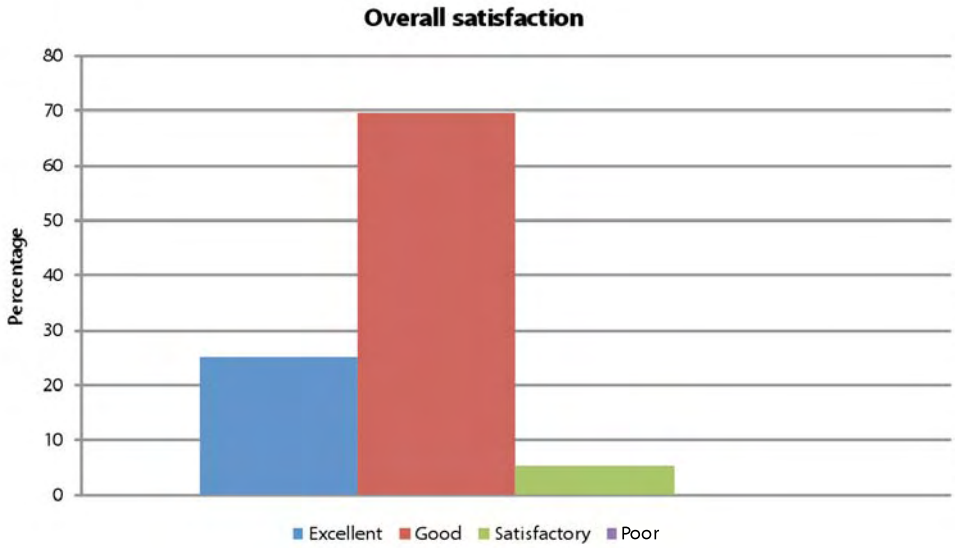
Appendix D: EVALUATION 1 (with Results)





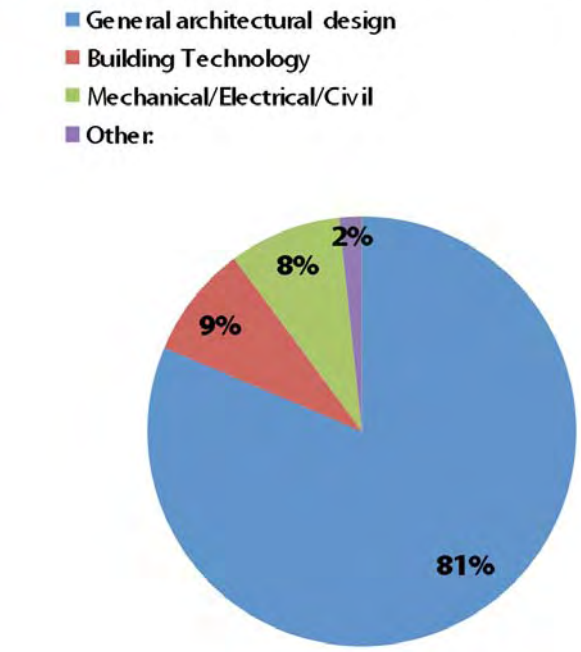



Audio Visual Material
Percentage
60
50
40
30
20
10
0
Related well to presentation
Was good quality
Was suffi cient in number
Excellent
Good
Satisfactory
Poor

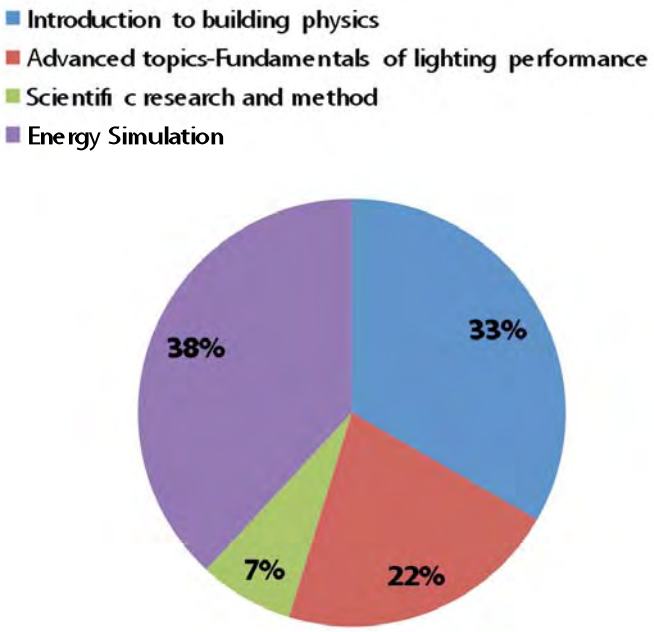

Overall satisfaction
Percentage
80
70
60
50
40
30
20
10
0
Excellent
Good
Satisfactory
Poor

Appendix E: EVALUATION 2 (with Results)

1. How do you characterize your educational background:

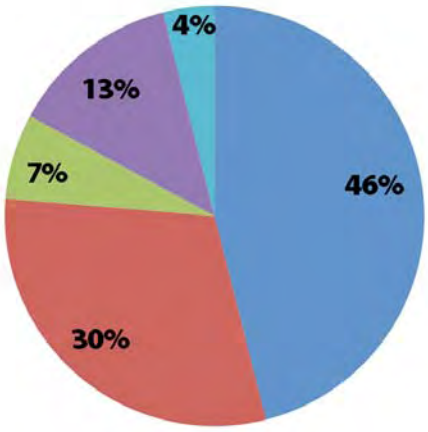


2. What thematic concentration at the workshop would be of most benefi t to you?



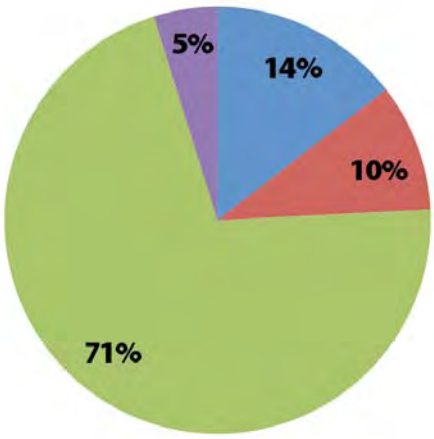
3. What area of building science architecture/engineering students are most interested in?

- Energy performance and thermal comfort
- Lighting Design/Daylighting
- Acoustics
- Load Calculation and Energy Simulation
- Other



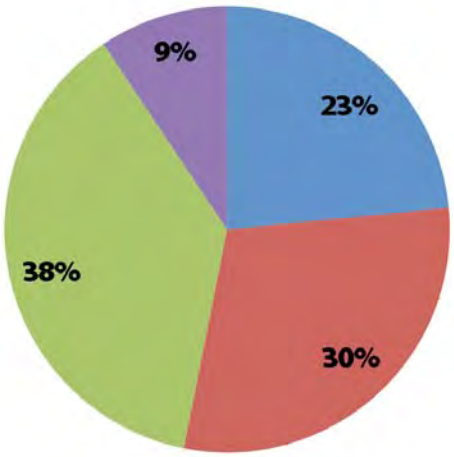
4. What is in your opinion the most promising approach to teach building science to architecture/engineering students?

- Emphasize foundations in physics and mathematics
- Forget equations, just work with rules of thumbs and lookup tables
- Provide the students with a qualitative feel for physical forces acting on buildings
- Othter



5. What is in your opinion the best way to apply the building science knowledge in a design studio or other building design assignment?

- Allocate a fixed % of marks on incorporation of sustainable design principles to the design project
- Require students to perform quantitative energy performance calculations as part of submission requirements
- Ask student to use principles and specifications used in energy code or green building rating systems(ECBC or LEED or Griha building)
- Other



Appendix F: TESTIMONIALS

"We found the workshop very informative and useful.We felt that Prof. Mahdavi gave an excellent overview of the physics behind simulations. We enjoyed Kristina's overview on DesignBuilder.

We feel that energy efficient design and energy simulations are very relevant to architectural education today, given the current global scenario of climate change. We hope that we can introduce simulations at the college level (especially in studios) and are hoping that we can potentially arrange workshops of this nature in our school.

We actually hoped to hear more about ECBC, hopefully, we can do so in the future. We'd also love to know about more simulation tools available today and a comparative analysis of each with the other."

Sumedha Amod Kumar,
Chandigarh College of Architecture, Punjab University, Chandigarh

"Building energy simulation in the current scenario is important in india because simulation data can not only help in calculating energy consumption for the life time of a building but can also help towards determining the energy conservation measures that can help reduce it. Therefore, in a developing country like india, building energy simulation can not only provide guidance towards minimizing consumption but also help to opt for alternative energy sources.

As far as the current status of energy simulation practices in india is concerned, there are some associations working towards it but the awareness if still low. Simulation training should start early during studies – at a graduate level – so that upcoming professionals are able to implement it in the field.

Courses like building physics, climatology, and energy simulation should definitely be included in the architectural education and curriculum. Today, as global warming and climate change has become a major issue of concern, timely implementation would make a lot of difference. These courses can easily become a part of the regular teaching and I feel that training student as well as teachers is an important step towards that aim.

Building physics was just a term for me, but after attending this workshop my knowledge as well as my inclination towards this subject has increased considerably. Some of the building simulation exercises and the ideas generated thereafter have provoked me to works on this subject and to take effective steps towards assisting its implementation.

Energy simulation workshop would help not only in academics but in profession as well. Such events help students as well as professionals to keep up-to-date with the latest knowledge. However, much more needs to be one. I hope with time things will exponentially improve. I also feel some competitions should be organized on such subjects to increase interest and awareness."

Tulika,
Babu Banarasi Das National Institute of Technology & Management, UP Technical University, Lucknow

"Energy simulation is the process which helps the designer to calculate the energy performance of the building. Thus, it is of considerable importance in the current architectural scenario in india. I feel that the status of energy simulation india is improving. Workshops, training sessions, etc., are being organized. Ecbc is being implemented which covers the five climatic zones of india. Energy Conservation Action Plans are being introduced in some of the states. There are projects where replacement for incandescent lamps by fluorescent lighting is being done in the residential sector under the Energy Efficient Lighting Program. So, there are lots of efforts being made in this direction but lot more needs to be done.

Including courses like building physics, climatology and energy simulation in the architectural curriculum is very important. I feel that these courses can be integrated with the existing structure with just a little more efforts, by introducing some extra lectures, additional workshops, training and software tools. These are issues and concerns of which each architect as well as student should be aware of.

This workshop had a great contribution towards enhancing my knowledge of building physics and energy simulation. The literature and reading material we got was very good. Even the software that was introduced was extremely useful. It all just makes one feel that energy efficiency is the way to go about designing buildings and one should start working on it right away. We were introduced to some very important ideas and principles during the workshop which I feel would definitely make a big difference if we work on them. So, we should try making use of these principles in our studio designs and by sharing our design ideas with others. I feel there is a big need to for more such events at different venues and colleges. These sessions should be integrated with our studios. I also feel that there is a need to introduce more simulation software like DesignBuilder."

Vartika Srivastava,
Babu Banarasi Das National Institute of Technology & Management, UP Technical University, Lucknow

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