Environmental Science for Architecture students – A Problem Based Learning approach

Hiten Chavda

Assistant Professor
School of Environment and Design
Navrachana University, Vadodara
hitenc@nuv.ac.in

ABSTRACT:

Environmental Science curriculum for Architectural studies is being upgraded in institutions throughout the Country, due to recent development of advanced analysis and thermal simulation software. On one hand the basics need to be taught and on the other hand Building design needs to be looked at with a performance based approach by thermally simulating the building. A Problem Based Learning approach with a mix of Hands-on learning techniques and learning from Software providing performance feedback is worked out and presented in this Paper.

This paper is based on last 3 years of curriculum planning and application resulting into improvisations in teaching methodology. The Author also takes Design Studio on Sustainable Development. All work done by students in these two subjects acts as a feedback for the curriculum developed. The paper gives an insight into Problem Based Learning methods developed utilizing physical as well as digital models. All the methodologies developed as mentioned in this paper contribute to developing better awareness about Climate sensitivity for Passive Solar Architecture and provide a firm base for design of Sustainable Buildings.

INTRODUCTION:

Environmental Science is a core subject for Architectural Studies. It forms the basis of Environmental Design and understanding Environment as a Context rather than constrain for design. Our discussion in this Paper concentrates on developing a curriculum for the subject with reference to Architectural education in the Indian Subcontinent.

Not much is known about this subject in the pre independence era, but discussions with senior Architects proves one fact that, Environmental Science was taught through the Vernacular Architecture and its response to the climate. This scenario changed in 1953

when the first draft of the book *Manual for Tropical Housing and Building* was published. The book provided many easy to use scientific methods to understand and quantify Environmental forces and their effects on the building. It also showed Graphical Calculators to understand the climatic effects on building and manage the sizes and proportions of various components of a built form. This brought a welcomed change in the way the subject was taught. It empowered the designer to have a better responsive building to the climatic forces. Till date this book continues to serve students in the Indian subcontinent with its revised volumes.

Various Precedents in teaching methods do exist, like Lectures and Presentations using visuals and graphs, Group discussions, Seminars, Pin Up reviews, Inquiry based learning, collaborative approach, Problem based learning, etc. For this subject we have attempted to utilize a combination of most of these techniques with an emphasis on Problem Based learning. Hence most of the classes would start with a unique issue to be resolved. Also there is a unique problem for each semester too.

With a focus on Sustainability the subject of Environment Science has to further improve or modify. Energy crisis in different parts of the world, forces Building industry to understand performance of a building. Advanced subjects like Post Occupancy Evaluation of buildings are now main-stream in advanced architectural studies. Also the advent of Simulation Software provides a much needed interface between design and performance of a building at the initial stage.

Looking at this changing scenario the author proposes the revised Curriculum for the subject. This curriculum has been implemented at School of Environment Design and Architecture, Navarachana University since May 2012 till now and is being further improvised based on the feedback from the students.

METHODOLOGY:

While developing the new curriculum, combination of different Teaching methods (uniquely suitable to explain various topics) have been worked out. Special attention is given to make the student use various Hands on Techniques and Software in order to explore the solutions. Aim is to educate students about the subtle technicalities of each topic by making them work towards a given problem. Kind of information to be imparted in Environment Science is mainly identified into 3 types.

a. Basic information: Nearly all basic information is imparted by Lectures, Presentations and Group discussions.

b. Exploration on given Problem: All explorations for a given problem are done by Hands on methods like Model Making, Graphical Calculations, physical measurements and pin up reviews.

c. Performance based feedback: Finally the performance based feedback is taken by Simulation Softwares.

Each session works in two halves. First is Information dissemination and second is assisting in problem solving. The Curriculum has been divided into three main parts based on Semesters.

1. Environmental Science-1: Passive Solar Techniques
   First Semester concentrates on introducing Climate as a Context for designing. This involves detailed understanding of Sun, Wind, Light, Climatic analysis, Basics of building physics, and Basics of Passive Solar strategies. Based on this, analysis of vernacular typologies and respective contemporary building would be done. University building would be taken up as a project for Passive Solar Renovation.
2. Environmental Science-2: Sustainable Development
   Second Semester concentrates on introducing sustainability. This will need detailed understanding of Day-light simulation, Thermal control, Micro climate generation, Sound and Building Acoustics, Advanced Passive Solar strategies. Based on this, analysis of vernacular typologies and respective contemporary building would be done. University building would be explored as a project for Post Occupancy Evaluation.
3. Environmental Science-3: Building Simulation
   Third Semester concentrates on introducing Building Thermal Simulation software for achieving comfort zone. All the explorations on the University building would be analysed using the software. Besides this, various Active and Passive environment control systems are studied.

Environmental Science -1:

Problem: In the First Semester the Problem defined for Students is to imagine their University Building is placed in a particular city of a particular Climatic Zone as identified in Appendix. This Building now needs to achieve Comfort Zone by Passive means.

Lectures: Hence contact hours with students go into clarifying the basics like...

a. Climate as a Context - Basic Course structure, Building as a Boxand Machine, Factors influencing a Built Environment: Sun, Wind, Rain, Vegetation, etc. Basics of MS Excel as a software.
b. Sun & Earth Relationship - Sun and Planetary Orbits, Solar Radiation, IR, Visible, UV, Heat, Effect of Sun on Seasons
c. Sun Path Dial - Sun Path Dials, Sun Path Diagrams, Altitude, Azimuth,
d. Game of Green Home Design - Game of Massing and Shading of a building
e. Sun Light Vs Solar Heat gain - Study of types of Openings
f. Wind & Ocean Currents – Study of types of Walls
g. Elements of Climate - Temperature, Precipitation, Humidity, Weather, Seasons and Climate.
h. Climatic Zones and Representation - Climatic zones, Ishrae data and graphical representation, Physiographic zones
i. Climate and Comfort – Comfort Zone
j. Window Design Challenge - External shading, Types of glazing, Flexible shading elements.
k. Wall and Roof design - Walls and Roof protection / Cooling
l. Climate Consultant software - Comfort temp, comfort humidity, comfort air change, Psychrometric Chart
m. Passive Solar Architecture - Shading, Insulating, Stack Ventilation, Trombe walls, Earth berming.

Solving Procedure: First part of the semester goes into knowing Sun's Movement, Climatic data, Effective Temperature, Comfort zone and solving the Passive issues on a Unicellular Block of 8m x 4m x 3m height. Students make a physical model and express their solutions on this model.

The 3-dimensional visuals of the Sun movement are shown taking visuals from Ecotect software to express the Sun Path during different times of the day and in different seasons. A Stereotype Sun-path Diagram is then explained as a 2 dimensional representation of the Sun-path Dial. Concepts of Altitude angle and Azimuth angle are clarified. The idea is

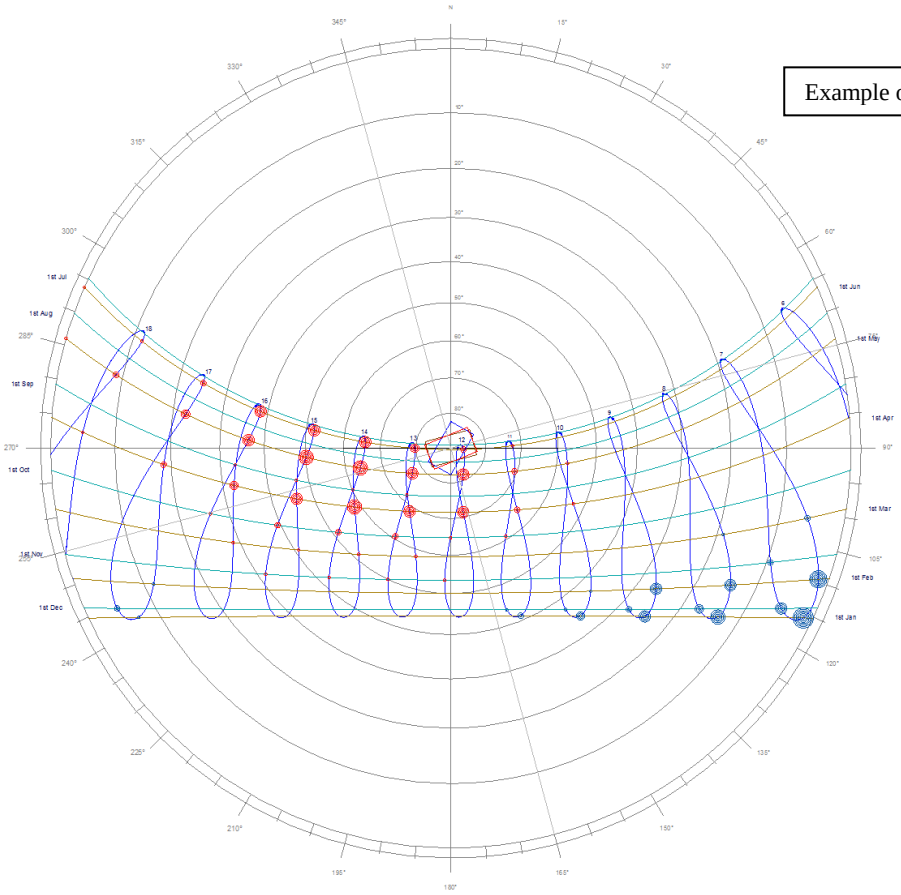
reinforced by expressing the Sun-path diagrams for different latitudes, explaining time span of the days on poles and solar angles in tropical regions.

By this time Climatic data of selected cities of different climatic zones are provided to the students to work in groups. Nine different Climatic Zones are identified based on Koeppen- Geiger Classification and about 22 different cities are selected with variation in Latitudes. The list of these cities is provided in the appendix. Climatic data of these cities are provided with a '.stat' file of the city which can be converted to a '.xls' file to be worked on Microsoft Excel. These files are obtained from the data of Ashrae web site as mentioned in the References. Along with this data the Sunpath Diagram of the particular city is also given.

Each group takes the data from the Excel file and using information of DBT and Humidity on Nomogram of Effective Temperature Isopleth, develops the Effective Temperature data. This data provides the effects of DBT and Air-change for a given Clothing value.

Comfort Zone is considered as Adaptive comfort zone as identified by Nicol & Humpherys equation. This data helps define the range of comfortable temperature for the occupant of the city.

On the Sunpath Diagram students mark the ET for a particular month and hour, in Red colour rings for temperature hotter and in Blue colour for temperature colder than comfort.



Example of Sun path diagram

Similarly Humidity is also plotted on the Sunpath Diagram. This enables Students to know that all the white portion of Sunpath is comfortable for occupants and all the Red portion is to be avoided. This method also provides the intensity of the sun in the hot zone which guides the orientation of the building as shown in the figure above.

In between the first exercise in the 4th or 5th week students are made to Play a Game of Magnetic Blocks called ‘Green Home Design’, designed and developed by the Author to promote Passive Solar Principals amongst School children. This gives students, hints of the probable solutions of their Problem set. A Climatic representation tool known as Climate Consultant is also taught to students helping them understand details of climatic analysis and suggestions on passive solutions.

As soon as the knowledge of Wind and displacement Ventilation comes up, the focus of class shifts to Multi-cellular Block that is the Entire University Building. This part of the exploration is done on Software of Trimble Sketchup, as this software provides exact Simulation of Sun path providing shadows. Here induced ventilation techniques like Stack

Vent, Trombe Wall, Conservatory, and Wind Scoop are explained and tried on the building. Exploration of types of Fenestrations and their combination at the larger level of the building is also worked out. Fenestrations explored in Uni-cellular model are represented as a series of images for different hours and Months to prove the validity of solution.

Final submission is in the form of a Uni-cellular model on the Sunpath diagram exhibiting Optimum Orientation for the given city, and also exhibiting the Fenestrations on each window. It also comprises of Report on Passive strategies for the Entire Building with submission of the Sketch up Model.

Environmental Science -2:

Problem: In the Second Semester the Problem defined for Students is to Design a Research Laboratory Building in a place of extreme climate, physical condition. This Building now needs to achieve Comfort Zone as well as needs to be Self Sufficing in terms of Energy, Water, Air, Waste, Earth and Biomass.

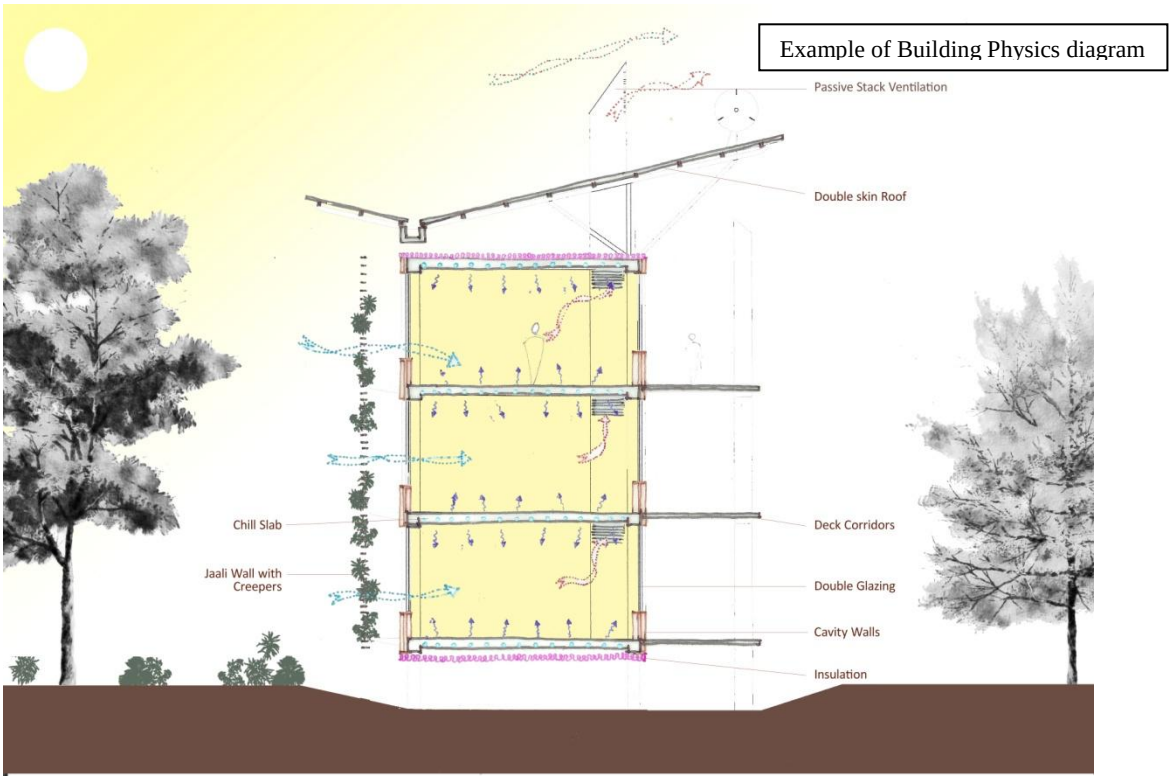
Lectures: This semester concentrates mainly on the Sustainable Development.

a. Climate and Vernacular - Building features developed for Environment protection.
b. Vernacular architecture and Passive Solar principals
c. Sustainable Development – Understanding Building as an organism / Machine and implications of anything going in and coming out. Student seminars explaining various technologies for managing Energy, Air, Water, Waste, Biomass and materials in a building.
d. Energy management in a building, Hi-induction load and low-induction loads, Renewable energy sources
e. Air management in a building, ventilation, infiltration, air exchange mechanisms.
f. Water management - optimization of consumption, harvesting, recycling.
g. Waste management – segregation, recycling, best out of waste
h. Biomass management – thermal buffer, sound buffer, native species, etc.
i. Building Materials – embedded energy, lifecycle, recycling.
j. Building Physics and Building Service diagrams.
k. Designing an observatory at a unique/extreme location and resolving the construction, sustainability issues of the building.

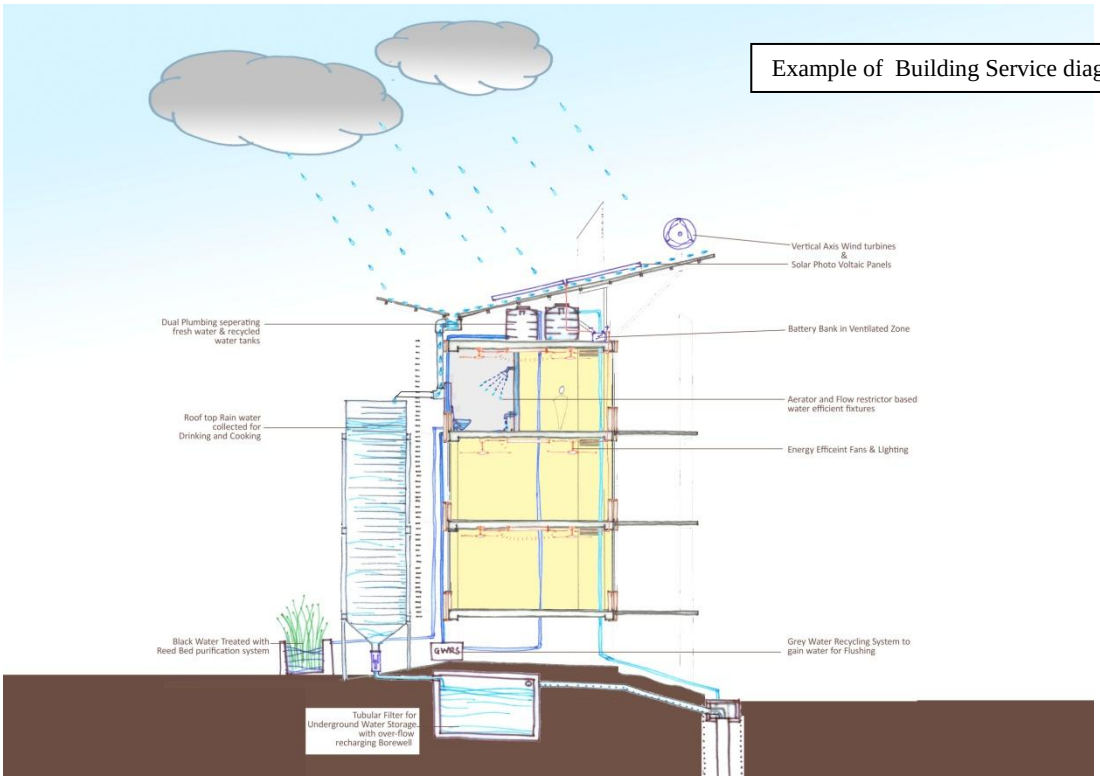
l. Application of Advanced features in Passive Solar Architecture - Stack Ventilation, Trombe walls, Earth tube heat exchangers, Passive Downdraft cooling system, etc.

Solving Procedure: This semester starts with understanding Vernacular Architecture and decoding its features that help in achieving comfort zone. Vernacular Architecture is analyzed from the point of view of Space Heating/Cooling, Rain Water protection, Humidity control, Day lighting, Ventilation, Buffer, security from Snakes and Rodents. Further analysis on constructional and structural efficiency as well as protection from Natural calamity like Earth Quake, Flood, Sand storm, Twister, etc is exhibited in form of Conceptual diagrams.

Project of a Research lab is worked out choosing an extreme site and analysing its climatic conditions. Parallel sessions of Seminars on Energy, Water, Air, Waste, Earth and Biomass run in the class along with discussion on the design problem. The design is supposed to be developed in the form of a Plan and a Sectional Profile. All passive solar features along with ventilation strategies and Building material information are exhibited in a Building Physics diagram.



Similarly on another sectional profile a Building service diagram expresses all Energy generation and conservation strategies, Water and Waste management strategies.



Example of Building Service diagram

The semester ends in submission of the Vernacular typology analysis, presentations of the seminar, and Building Physics and Building Service diagrams.

Environmental Science – 3:

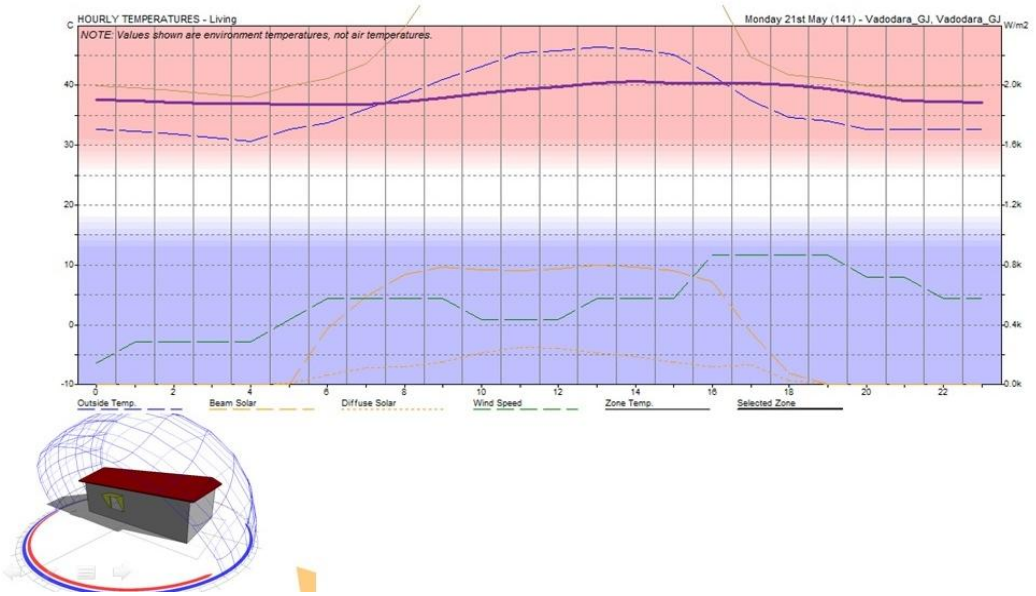
Problem: In the Third Semester the Problem defined for Students is to achieve Comfort zone for a unicellular space of 8m x 4m x 3m height in the given climate by using the Software of Autodesk Ecotect. This exercise enables students to learn the software quickly. Second half of the Semester focuses on simulation of the Studio project of Housing in the same software. Aim here is to achieve a design with minimum Energy Performance Index.

Lectures: This semester concentrates mainly on Building Thermal Simulation.

a. First session is to clarify the basic calculations of Building Physics with the help of *Manual of Tropical Housing and Building*.
b. *Autodesk Ecotect* as a software is introduced, with basic layout and protocols of drawing and simulating.
c. Drawing of Zones and Openings are worked out with default settings of wall types to check inside temperatures.

d. Now inside temperatures are checked by modifying the window sizes of different walls.
e. Also inside temperatures are checked by changing the orientation angles of the building.
f. Material properties of all building components are modified to check thermal performance.
g. Schedules are added to the model information system, to account for Occupancy, Equipment and Infiltration.
h. Glazing type and Fenestration are worked out for different windows
i. Another Zone defined as a Roof, Thermal Buffer, Conservatory, Green House, Thermal Mass, Trombe Wall, or Insulation is worked out to gain benefit in Inside Temperature.
j. Finally Energy Performance Index is obtained of the Building as base case and further fine tuning is attempted to Lower down the EPI by Half of original.
k. Housing Studio design is explored on Ecotect. Parallel to this, Green building Rating system of different countriesare explained to students and by students as a seminar.

Solving Procedure: This semester is dedicated to learn Simulation software and to know the latest in Green Building Rating and Technologies around the world. Hence a unicellular space is drawn and simulated in Ecotect. The aim here remains to bring the inside temperature to comfort zone and reduce the EPI value of the space by using various kinds of materials, various orientations, Buffers, and Schedules. At the end of the exercise students become confident in using the software and can apply the knowledge for their Housing Studio exercise. Further students are exposed to various Green Building Rating systems around the world. Each rating system usually has a set of criteria which if fulfilled provides the owner with certain Points. Here students explain the rating system in terms of their Point by showing visuals of the best case examples. The exercise also helps in knowing the latest Green building technologies in different parts of the world.



SUMMARY:

It has been observed by the feedback from Students that the module is really enjoyable and provides knowledge in a playful way. We gain few unique advantages by such a curriculum, as listed below.

- Enhanced Sensitivity towards Climate as a context in Architecture, with detailed information from Climate Consultant Softwares.
- Enhanced Clarity on issues of Thermal performance its relation with Building materials, buffer functions, etc.
- Expertise on various methods to solve the problem including Hands on, Graph and Nomogram based and software based.
- Empowering students with a range of skill-set and approaches to deal with the issues
- Healthy combination of Presentations, Group discussion, Hands on, and Software based.

ACKNOWLEDGEMENTS:

The curriculum designed is viable for the Indian Subcontinent and Tropical regions around the world. It would be updated in future as knowledge updates. Care has been taken to provide students with Softwares which are either open source or available free to student community, for greater applicability of the curriculum.

I thank Prof. Gurdevsingh for giving me a chance to explore and detail out the curriculum and helping with discussions in understanding Problem Based Learning as an approach to teaching. I also thank Ar. Khushboo my teaching assistant for painstakingly converting the ET isopleths on Sunpath diagram into a Cad drawing.

Further improvement would be achieved based on Feedback based refinement of the curriculum. I thank the Students of NU for providing honest feedback at the end of semesters.

REFERENCE:

1. Koenigsberger et al.: Manual of Tropical Housing and Building: Climatic Design
2. Brown G.Z.: Sun, Wind and Light
3. Ed. Santamouris M. & Asimakopoulous D.(1996): Passive Cooling of Buildings, James & James
4. Givoni B. (1994) Passive and low energy cooling of buildings
5. Nicol F, Humpherys M & Roaf S.(2012): Adaptive Thermal Comfort – Principals and Practice, Routledge

WEBSITE:

6. ASHRAE website: http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data2.cfm/region=2_asia_wmo_region_2
7. Climate Consultant: http://www.energy-design-tools.aud.ucla.edu/

APPENDIX:

Tutorials: Environment Studies-1:

Class	Topics	Sub Topics	Project work
1	Climate as a Context	Basic Course structure, Building as a Box, and Machine, Factors influencing a Built Environment: Sun, Wind, Rain, Vegetation, etc., Basics of Excel as a software	Model of University Building
2	Sun & Earth	Sun and Planetary Orbits, Solar Radiation, IR, Visible, UV, Heat, Effect of Sun on Seasons	Get a Sunpath Dial, Multiple copies
3	Sun Path Dial	Sun Path Dials, Sun Path Diagrams, Altitude, Azimuth,	Best orientation of Uni Building on Sunpath Dial
4	Game	Game of Massing and Shading of a building	Play Game and Evaluate

5	Sun Light	Study of Types of Openings	With different windows
6	Sun's Heat	Study of Types of Walls	Thermal Mass, Insulation, Double Skin, Reflective,
7	Wind & Ocean currents	Wind patterns at Global level, Wind and Seasons, Wind speed, Wind directions	Create Wind rose for all important cities of Gujarat
8	Elements of Climate	Temperature, Precipitation, Humidity, Weather, Seasons and Climate.	Get weather data of various cities of Gujarat
9	Climatic Zones & representation	Climatic zones, ASHRAE data and graphical representation, Physiographic zones	Climatic data representation charts
10	Climate & Comfort	Comfort Zone	Create Physiographic zone Map of India
11	Window Design Challenge	External shading, Types of glazing, Flexible shading elements.	Building study on Sunpath Dial, Design windows for all four orientations, with Shadow study
12	Walls & Roof Design challenge	Walls and Roof protection / Cooling	
13	Climate Consultant & Psychrometric Chart	Comfort temp, comfort humidity, comfort airchange, Psychrometric Chart	Comfort Zone on a Sunpath dial, Develop Psychromatric chart for important cities
14	Passive Solar Architecture	Shading, Insulating, Stack Ventilation, Trombe walls, Earth berming.	Design Shading devices for your building
15	EXAMS		

Tutorials: Environment Studies-2:

Class	Topics	Sub Topics	Project work
1	Climate and Vernacular	Building features developed for Environment protection	Analyse a vernacular typology of a climate
2	Vernacular Architecture	Building features developed for Environment protection	Climate and effect on building Typology
3	Vernacular Architecture	Diagrams to represent Sustainability	Represent on A3 sheets
4	Six Strands of Sustainability	**E**nergy, **W**ater, **A**ir, **W**aste, **E**arth, **B**iomass	Make Presentation on different issues of EWAWEB
5	Project Work	Design a Science Lab in an extreme location	Climatic study and Observations
6	Energy management	Presentation on Energy Generation, Optimization, etc	Seminar on Energy and Sustainability
7	Designing for Daylighting	Day lighting for Office and Residential use, Lux vs Lumen, Task, Focus, Wash, lighting.	Presentation on Daylighting and Energy
8	Water management	Presentation on RWH, Optimization, & Reuse	Seminar on Water and Sustainability
9	Building Physics Diagram	Develop a design and express its Building Physics with a Diagram with Heat Exchange, Thermal mass, U-Values,	Development of Project work in the form of Building Physics
10	Air Management	Presentation on Air, Filteration, Purification, Displacement Ventilation, Air conditioning,	Seminar on Air and Sustainability
11	Advanced Passive Cooling Technology	Evaporative cooling, ETHE, Earth coupled, Wind Scoop	Development of Project work in the form of Advanced HVAC techniques

12	Waste Management	Presentation on Waste optimization, segregation, Recycling, landfill,	Seminar on Waste and Sustainability
13	Building Service Diagrams	Develop a Building Service diagram expressing Water, Waste, and Energy systems	Development of Project work in the form of Building Services
14	Earth & Building Materials	Presentation on Low embodied energy materials, optimization, and recycling of material	Seminar on Building Materials and Sustainability
15	Micro-climate generation	Eco-systems around built environment,	
16	Vegetation & Sound	Evapo-transpiration, Indigenous plantation, Canopy trees,Acoustic buffers, Db	Different trees and plants for different purpose
17	EXAMS		

Tutorials: Environment Studies-3:

Class	Topics	Sub Topics	Project work
1	Semester Briefing		
2	Calculations	Building Thermal Calculations Theory	Refer to Text book
3	Auto Desk - ECOTECT	Designing for different climatic Zones on the Subcontinent	
4	Design Simulation - Model making	Zones, Openings	Create Model and PPT
5	Design Simulation - Simulation	Optimum Orientation	
6	Design Simulation - Properties	Material Properties and Schedules	Update Model
7	Design Simulation - Opening	Type of Glazing and Fenestrations	Update Model
8	Passive Technology	Buffer, Conservatory, Green House, Thermal Mass, Insulation	Update Model
9	Design Resolution	Optimization and Energy Performance Index	Update Model
10	Parallel sessions - Design and Presentation	Design Housing Problem in Ecotect and Presentation on Green Building Rating systems	
11	Green Building Rating systems	Different countries and rating systems, Points systems and effect on buildings	
12	Green Building Rating systems	Seminar	Presentation
13	Green Building Rating systems	Seminar	Presentation
14	Green Building Rating systems	Seminar	Presentation
15	Green Building Rating systems	Seminar	Presentation

Climatic Zones:

Nine different Climatic Zones are identified based on Koppen Geigger Classification and different cities are selected with variation in Latitudes.

1. Tropical Wet (Am):
    a. Panjim (Goa)
    b. Thiruvanantpuram(Kerala)
    c. Hambantota (Sri-Lanka)
2. Sub Tropical Warm Dry (As):
    a. Akola (Maharashtra)
    b. Indore (Madhya-Pradesh)
3. Sub Tropical Warm Humid (Aw):
    a. Bhubaneswar (Orissa)
    b. Mangalore (Karnataka)
    c. Vishakhapatnam (Andhra Pradesh)
4. Hot Semi Arid (BSh):
    a. Ahmedabad (Gujarat)
    b. New Delhi (Delhi)
    c. Solapur (Maharastra)
5. Hot Desert (BWh):
    a. Bikaner (Rajasthan)
    b. Jaisalmer (Rajasthan)
    c. Karachi (Pakistan)
6. Highland Savannah (Csa)
    a. Allahabad (Uttarpradesh)
    b. Bhopal (Madhyapradesh)
7. Highland Subtropical (Cwa):
    a. Dehradun (Uttarakhand)
    b. Gorakhpur (Uttarpradesh)
    c. Imphal (Manipur)
8. Hilly Continental (Dwd):
    a. Thimphu (Bhutan)
9. Tundra Desert (ET)
    a. Lhasa (Tibet)
    b. Nyingchi (Tibet)