Inventing Green

Re-thinking the Materials, Design and Delivery of Energy Products in the Developing World





Inventing Green Report

the Lemelson foundation
improving lives through invention

SELCO FOUNDATION

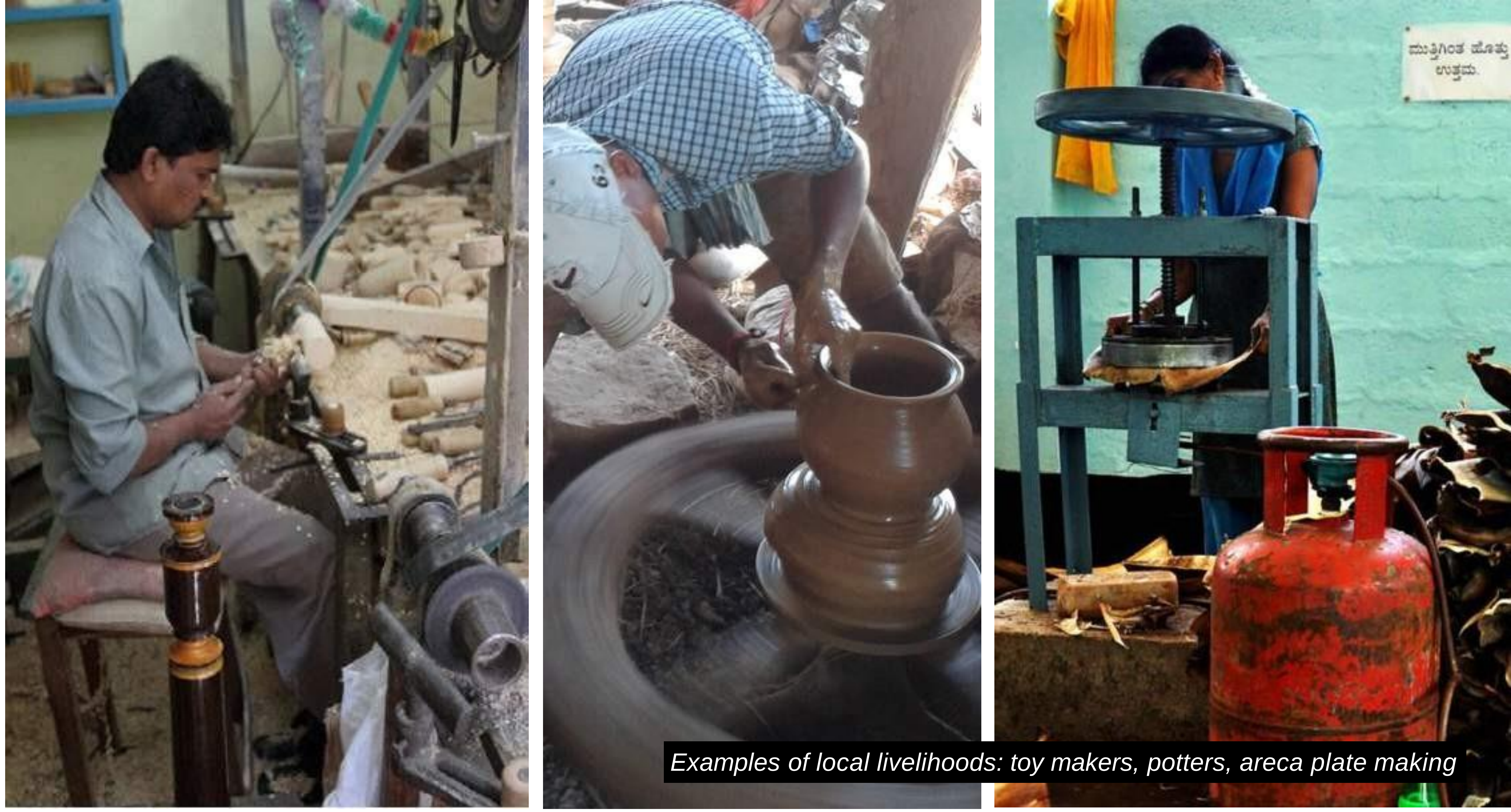
Contents

the Lemelson foundation
improving lives through invention

SELCO FOUNDATION

More than 95% of the estimated population of 1.2 billion un-electrified people live in developing countries. Investments in the clean energy sector focused on developing countries have been attracting over 100 billion dollars year after year since 2014. Parts of those investments have been done in the social space focusing specifically on the poor and vulnerable populations in developing and under developed countries.

Environmental sustainability being one of the important ways to deliver energy services to the poor, impacts need to be measured across extraction, production, distribution and end of life. Many queries are being raised about measuring actual environmental impacts and deriving maximum value for the money invested by ensuring energy access can be implemented in a way that is socially, environmentally and financially sustainable. Typical clean energy investments are currently measured purely on the basis of financials or on the basis of the carbon replaced in the use phase or generation phase of the product only. Sustainability impact however, is more complex as it also needs to take into account overall social and environmental sustainability.



Examples of local livelihoods: toy makers, potters, areca plate making

About

One of the methods of measuring end to end environmental impacts is to conduct Life Cycle Assessments on the clean energy products being sold in the developing countries. The goal of project 1 within the inventing green theme is to develop low embodied energy (or carbon neutral) products, services and systems by impacting local livelihoods. The first step in order to achieve this, is to redesign materials, forms and delivery mechanisms of decentralized renewable energy products in India.

Examples of common Decentralized Renewable Energy end users: livelihoods, households and street lighting

SELCO FOUNDATION

the Lemelson foundation
improving lives through invention

Developing and undeveloped countries often have:

-poor manufacturing capabilities (most parts and products are imported)

-poor recycling infrastructure

-poor awareness and education on sustainable materials and forms

-poor thought process on decentralization of processes

-lack of livelihood generation and local empowerment within end user communities

Inventing Green is structured as a project that can push the boundaries of sustainability by bringing the gap between education and implementation of environmentally sustainable solutions. Students, faculty and industry experts in the space of Decentralize Renewable Energy over the past year, worked together to create inventions and innovations to positively impact the environment by:

- **replacing the materials and forms of the existing renewable/ sustainable energy products** (light fixtures, battery boxes, packaging etc.) with alternative options to significantly improve the sustainability quotient of the system.

Examples of parts and types of renewable energy systems that were re-developed using natural materials and local craftsman skills

Project Brief

- **leveraging student interest and expertise across socio-cultural backgrounds** (from the 'developed' and 'developing' worlds).
- designing end results through **curriculum based activities** including in-depth research and development of feasible and viable forms and materials generated through immersive explorations.
- understanding the strengths and weaknesses of **crafts and cottage industry based indigenous communities that work with locally available natural materials.**

Examples of chosen local materials

SELCO FOUNDATION

the Lemelson foundation
improving lives through invention

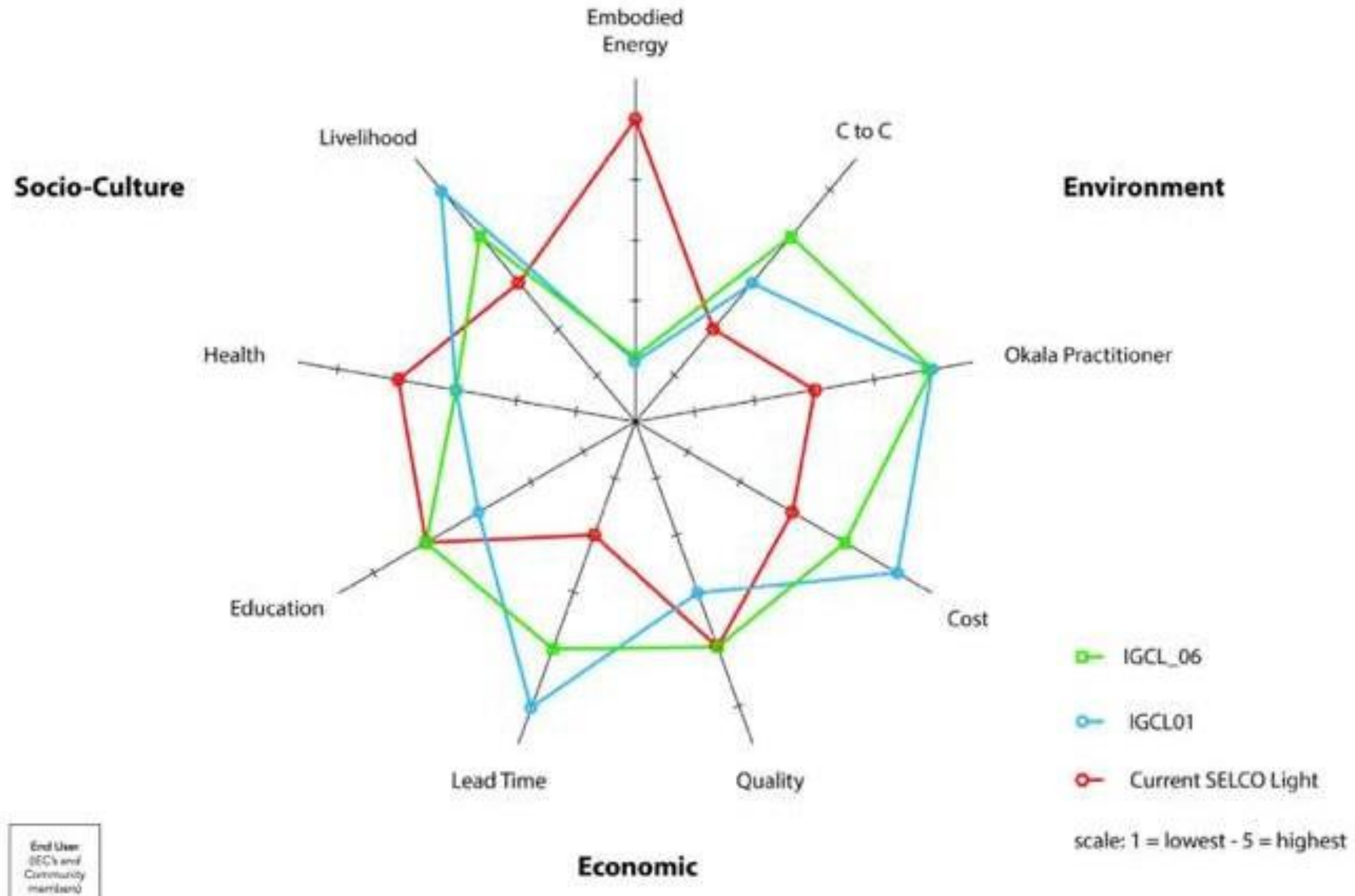
University Partnership 1: **Srishti Institute of Art, Design & Technology**

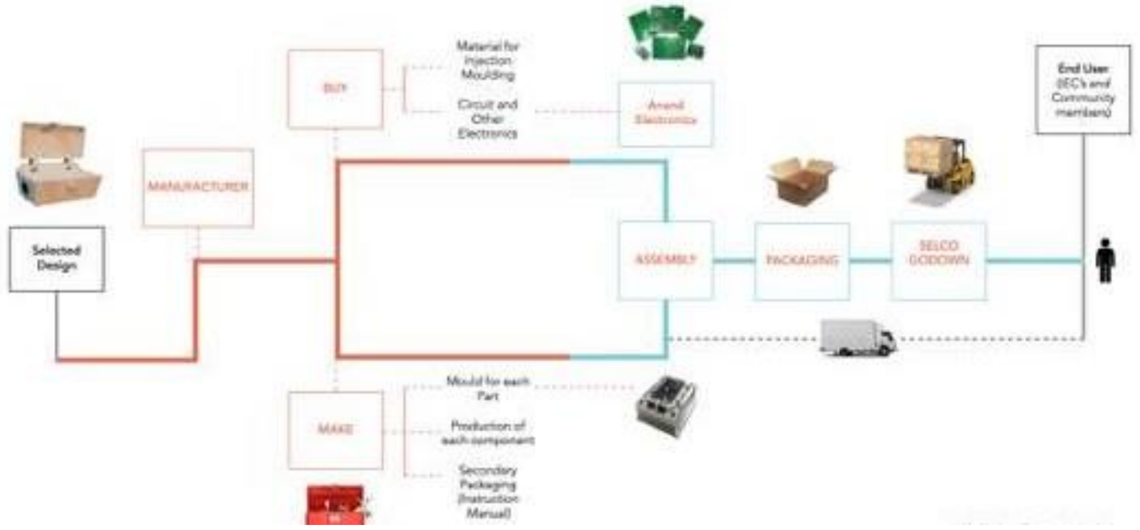
Srishti is a private design school set up in 1996 by the Ujwal Trust in Bangalore, India. The Srishti Institute of Art, Design and Technology is a visionary, experimental and curatorial institute of media arts and sciences, that offers art and design education at the undergraduate, post-graduate and PhD levels. Srishti promotes interdisciplinary platforms as a mode of enquiry and creative action.

With Srishti SELCO Foundation used an **integrated approach** to re-designing forms and functions by prioritizing material selection, manufacturing processes, types of stakeholders and supply chains for renewable energy components. The aim of the project was to convert renewable energy systems into truly sustainable energy systems by re-looking at the embodied energy of the entire system and such that it's not just the solar panel that is "green".

Students through the project discovered the feasibility of using alternative eco-friendly materials for product design and development in renewable energy systems. This was done by using a specific example of a renewable energy system and dwelling into its components such as light fixtures, model mounting structures, battery boxes, street light poles, packaging of the systems etc.

CRADLE TO CRADLE FACTORS	SELCO LED HL	RECYCLED CLOTH +RESIN	COIR + RESIN	JUTE+RESIN	MDF
Sun as income	✗	✗	✓	✗	✗
Native to context	✓	✓	✓	✓	✓
Waste as input	✗	✓	✓	✓	✓
Air, soil, water - friendly	✗	✓	✓	✓	✓
Design enjoyment for all (over time)	✓	✓	✓	✓	✓
Accessibility,mobility inclusiveness,	✓	✓	✓	✓	✓
Frugal Design	✗	✓	✓	✓	✓





EMBODIED ENERGY CALCULATION

$$\text{Embodied Energy – Assembly} = \frac{\text{Weight of material} \times \text{EE value MJ/kg} + \text{Weight of material} \times \text{EE value MJ/kg}}{\text{Total weight of all the materials}}$$

curriculum activities

Srishti

- **Course work**
- Curriculum Building
- Inventive Concepts
- Prototyping
- Next Steps

field visits

THEMES COVERED: SOCIAL ENTERPRISE, RENEWABLE ENERGY PRODUCTS, EXPLORING NATURAL MATERIALS, REVIVING LOCAL CRAFTS, ECOSYSTEM MAPPING AND LIFE CYCLE ANALYSIS.

IMMERSIVE STUDY AND FEILD VISITS TO END USERS, VENDORS, AND PRODUCTION AND DISTRIBUTION CENTERS

EMBODIED ENERGY CALCULATIONS (OKALA PRACTITIONER GUIDE)

SOCIO-CULTURAL, ECONOMIC AND ENVIRONMENTAL RADAR CHARTS

CONCEPT GENERATION AND PROTOTYPING

PRODUCT AND SUPPLY CHAIN ANALYSIS

SYSTEM DESIGN AND POTENTIAL BUSINESS MODEL

Main features of the course carried out at Srishti

SELCO FOUNDATION

the Lemelson foundation
improving lives through invention

3 Faculty members from Srishti together with the SELCO Foundation and a graphic designer worked on developing a curriculum outline for the Srishti Course to be replicated by other institutes. Each lesson is a set of eight cards, with images. These pages are used to create booklets OR create cut to size cards OR make them available on online platforms.

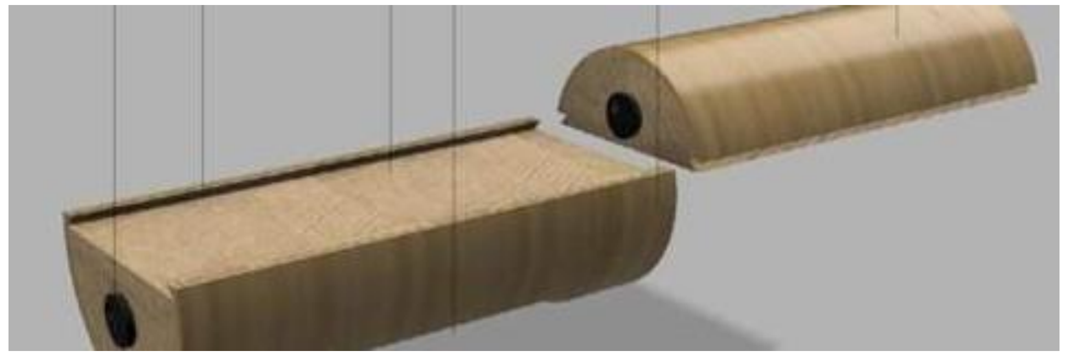
Snapshot from the curriculum outline

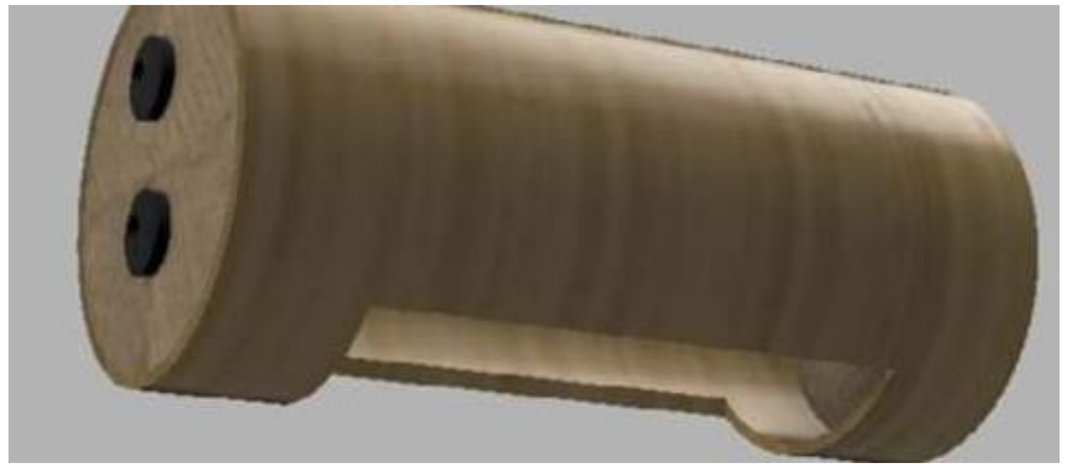
Srishti

- Course work
- **Curriculum Building**
- Inventive Concepts
- Prototyping
- Next Steps

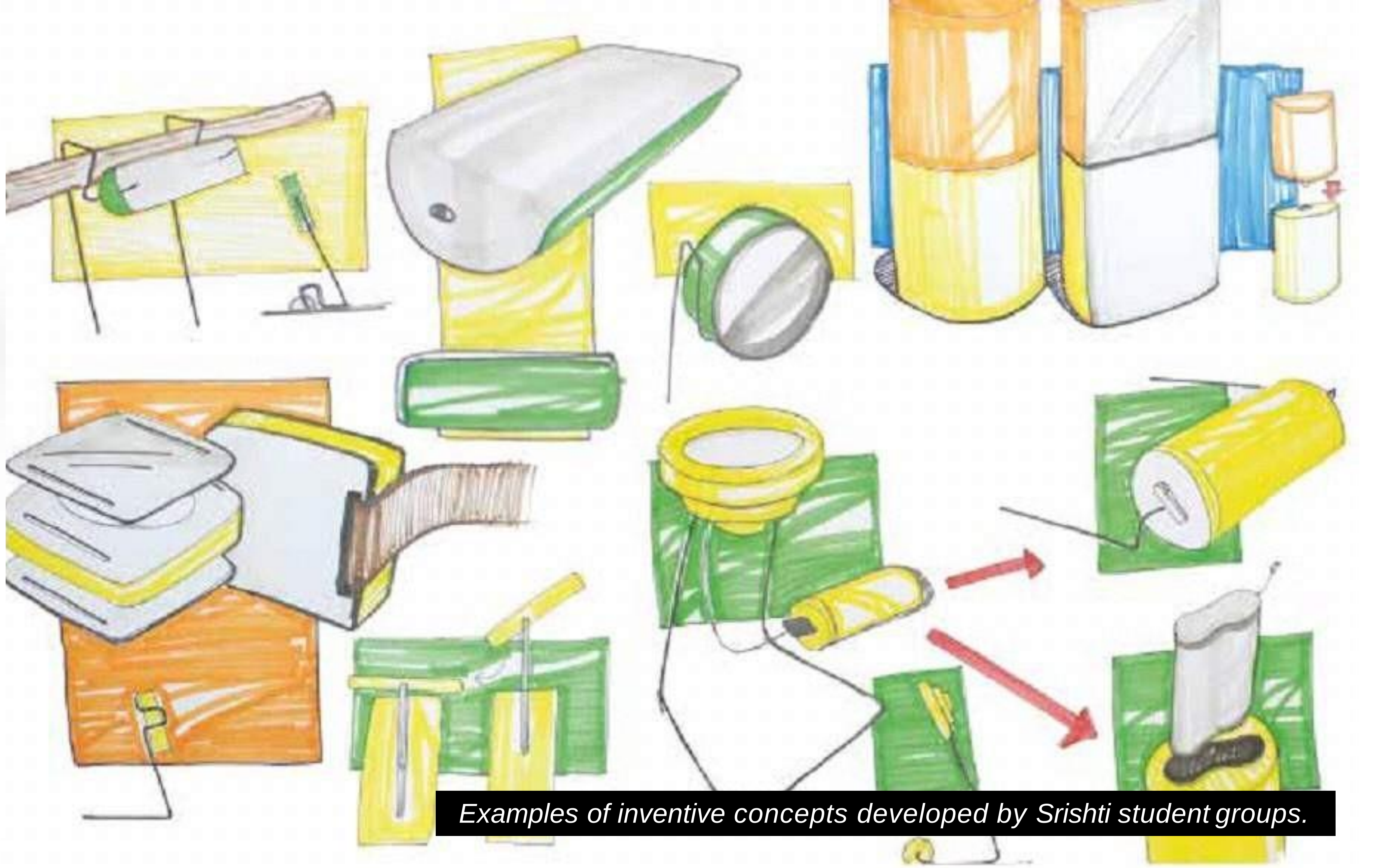
the Lemelson foundation
improving lives through invention

Eight inventive concepts developed by Srishti students included wooden lac craft design, a bamboo design and multiple coir, wood and coconut husk explorations. Two of chosen innovations from Srishti are discussed in the 'chosen designs' sections.





1

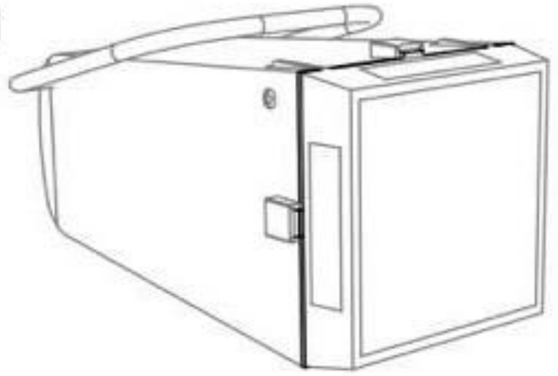


Examples of inventive concepts developed by Srishti student groups.

Srishti

- Course work
- Curriculum Building
- **Inventive Concepts**
- Prototyping
- Next Steps

1



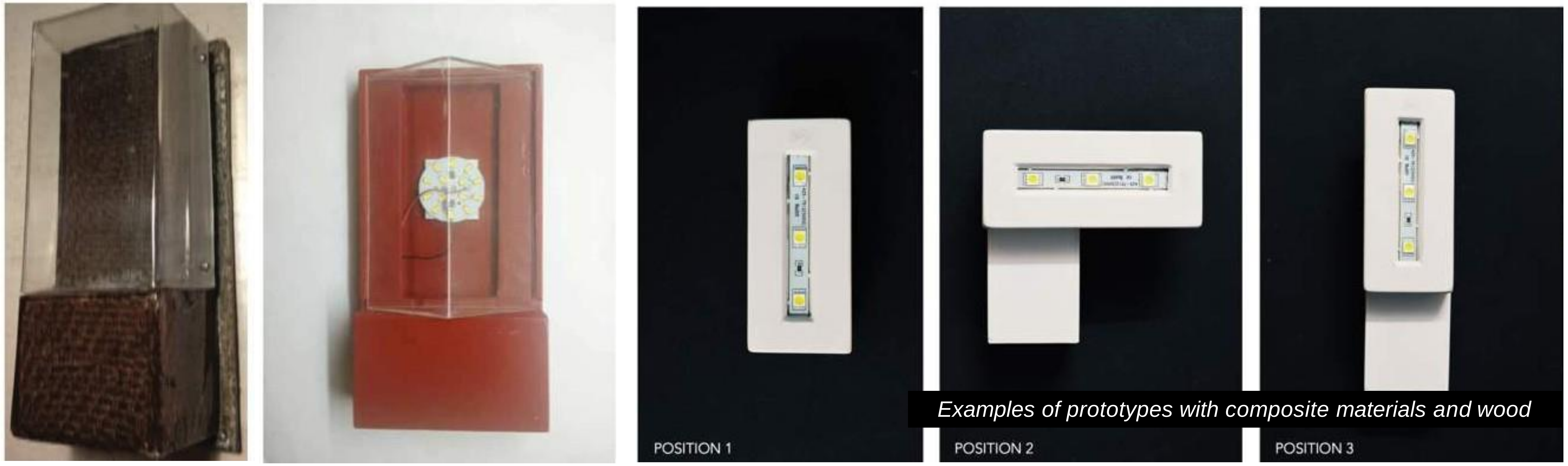
the Lemelson foundation
improving lives through invention

Multiple prototypes included coir, resin, jute experiments and bamboo and wood full scale prototypes.

Examples of prototypes with jute, cour, resin and bamboo

Srishti

- Course work
- Curriculum Building
- Inventive Concepts
- **Prototyping**
- Next Steps



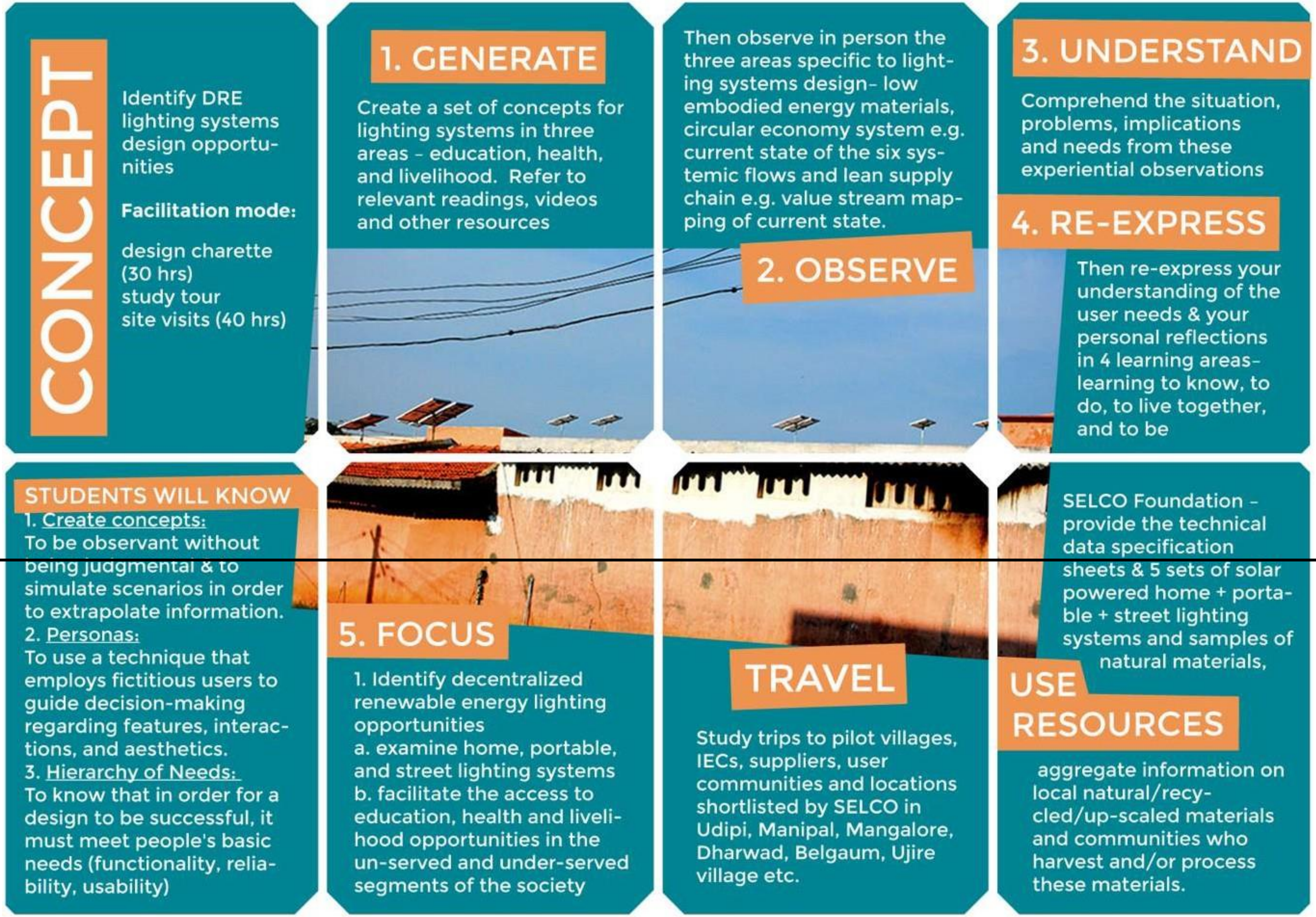
Examples of prototypes with composite materials and wood

SELCO FOUNDATION

the Lemelson foundation
improving lives through invention

After the Srishti course, SELCO Foundation continued to work with Srishti faculty on refining and designing the curriculum in a format that can be used by future universities.

Two Srishiti students continue to work with SELCO Foundation taking forward the Inventing Green designs.



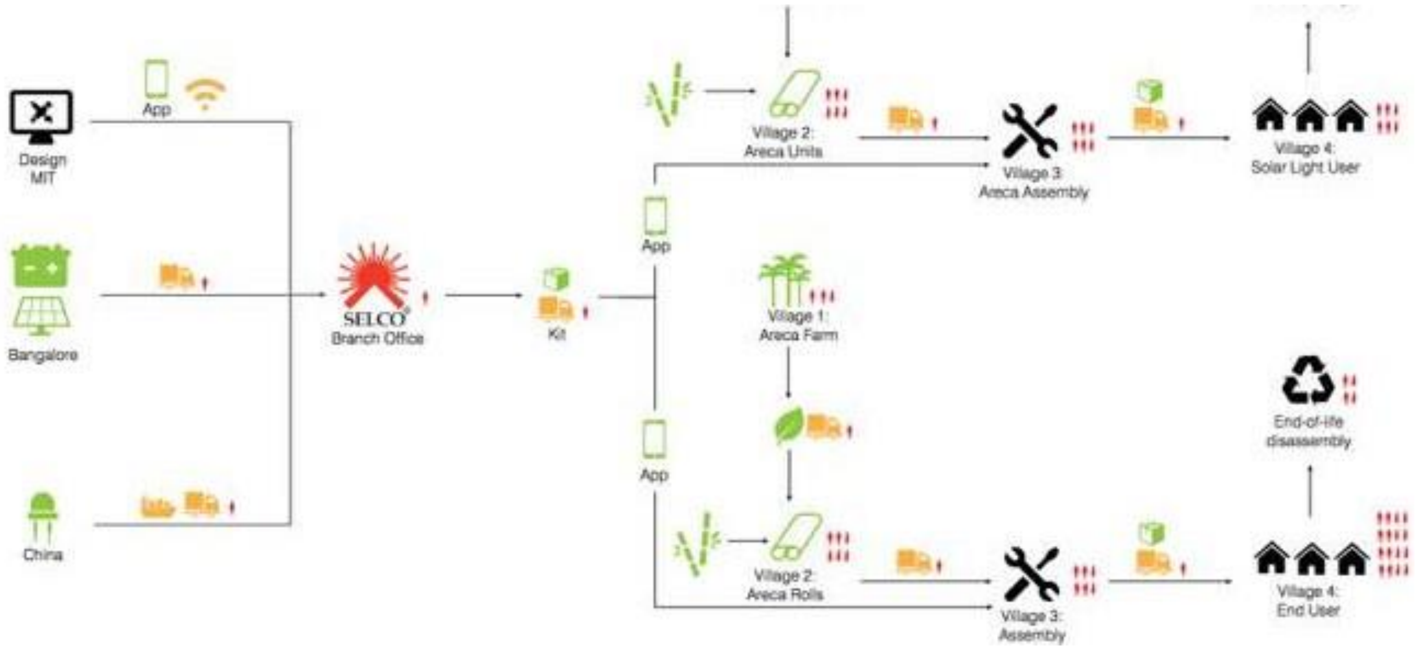
Snapshot from the curriculum outline

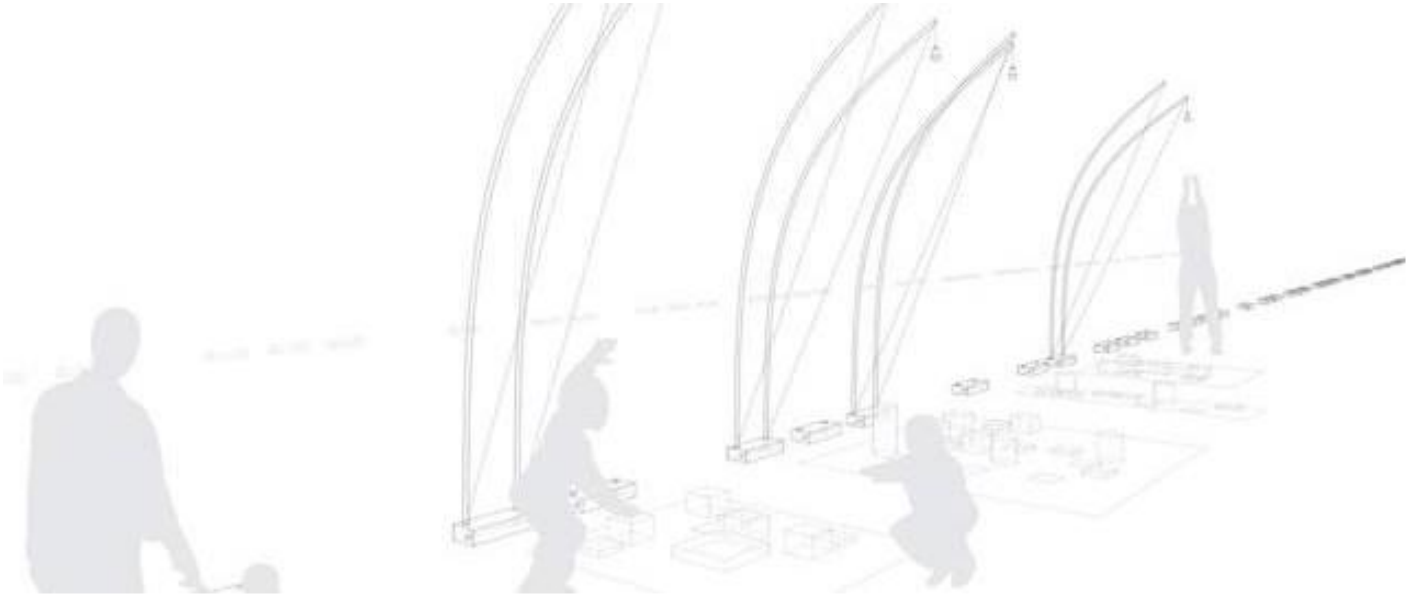
Srishti

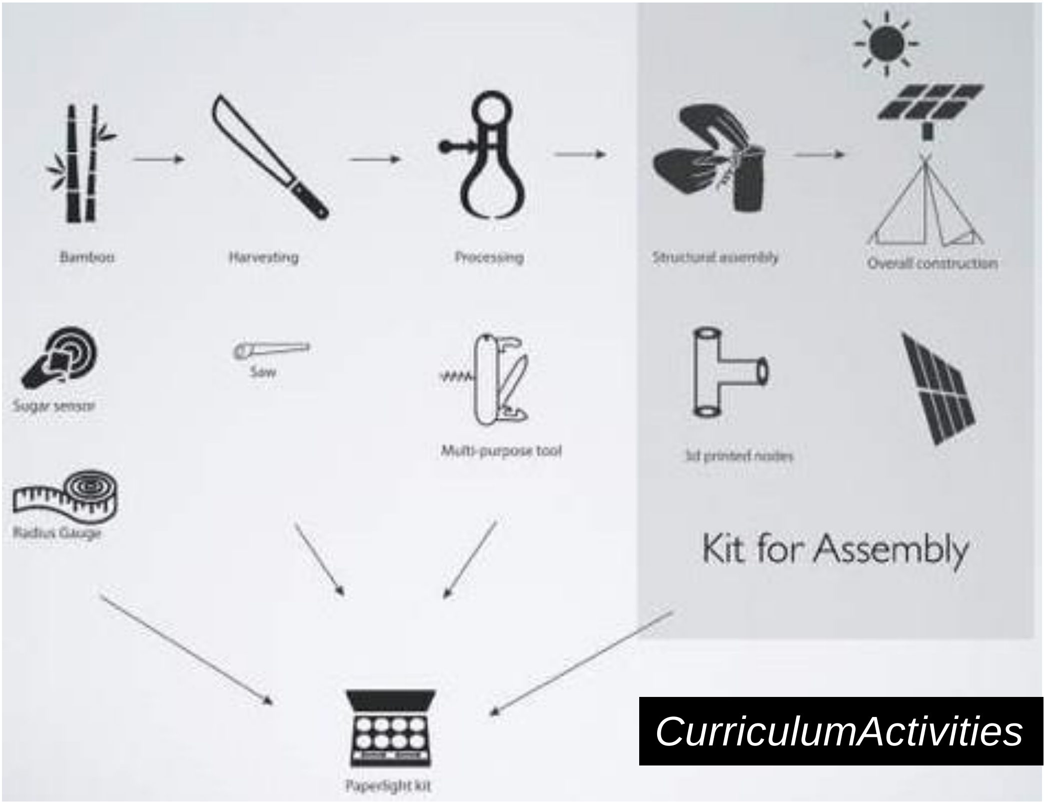
- Course work
- Curriculum Building
- Inventive Concepts
- Prototyping
- **Next Steps**

University Partnership 2: Sheila Kennedy from **Kennedy & Violich Architecture conducted** an interdisciplinary spring seminar/workshop of Inventing Green at **Massachusetts Institute of Technology.** The course explored the future of the solar streetlight as an emergent category of soft urban/ rural infrastructure: lightweight, locally made, low carbon, multiple, distributed and networked. As self-sufficient urban infrastructure that operates at the intermediate scale—neither furniture nor mega-building—the next generation of distributed infrastructure holds a unique scalar potential to create new forms of public space and improve the quality of life in rapid growth cities and urbanizing regions. To address these challenges, the need to design and fabricate strategies that are agile and adaptable, that merge hi/ low technologies, and local/ global networks, that can work in the developing and developed contexts were explored.

Students studied open-source digital design and distributed manufacturing models like Open Desk, 1000K garages, and others. They developed concepts for how their solar streetlight prototypes can be delivered online and fabricated by local maker communities in India to reduce cost, global shipping and carbon emissions. The workshop fostered an iterative and collaborative design process that valued craft, experimentation, testing and making.



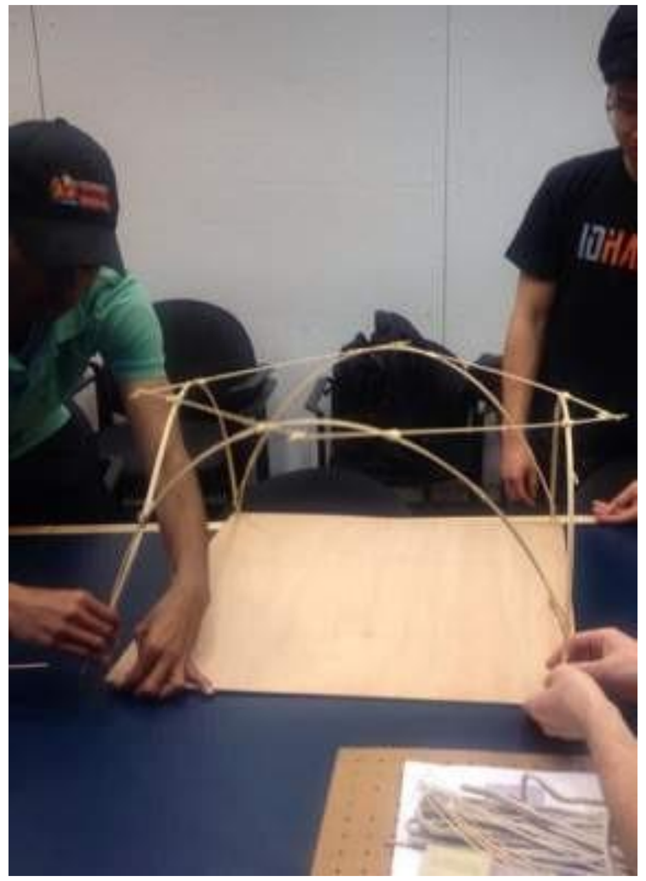




CurriculumActivities

KVA / MIT

- **Course work**
- Curriculum Building
- Inventive Concepts
- Prototyping
- Next Steps



Lecture sessions

INTRODUCTION TO MATERIALS AND STREET LIGHT SYSTEMS, CONCEPT GENERATION AND PROTOTYPING

BETWEEN PRIVATIZATION AND PUBLIC GOOD : DISRUPTIVE INNOVATION

FLAT TO FORM : INVENTION PRECEDENTS IN SUSTAINABLE DESIGN

WASTE STREAMS AND CARBON

DISTRIBUTED MANUFACTURING AND DISTRIBUTED FACTORIES

PRODUCT AND SUPPLY CHAIN ANALYSIS

POLITICS OF ARTIFACTS

INNOVATIVE DECENTRALIZED SYSTEM DESIGN

Features of the course carried out at MIT

SELCO FOUNDATION

the Lemelson foundation
improving lives through invention

Inventing Green curriculum for MIT was developed by a faculty member, a teaching assistant and a research assistant. Lectures were alternated by special sessions on users, context, vendors, need, computation etc. Each lecture covered a type of thought process such as decentralized manufacturing, design precedents with natural materials and more. Student teams worked on one project each through out the semester which was further divided into small and large assignments. Each lecture has a corresponding l ist of recommended readings, links and videos. Students had to prototype and experiment consistently to meet the weekly assignment requirements.

KVA / MIT

- Course work
- **Curriculum Building**
- Inventive Concepts
- Prototyping
- Next Steps

MIT 4.148

PAPER LIGHT WORKSHOP

Design for Low Carbon Pop Up Streetlights

Prof. Sheila Kennedy, MIT SA+P
RA: Huda Jaffer, MIT IDM
TA: Scott Penman

MIT 4.184 PAPER LIGHT WORKSHOP

Instructor: Prof. S. Kennedy
RA: Huda Jaffer, SELCO
TA: Scott Penman, Smarchs Computation

ASSIGNMENT 2: Design Object to Open System
DRAFT due 28 March to be discussed informally in class

Problem Statement
This exercise asks students to expand their pop up solar streetlight concepts from a singular object (based upon a set of material properties and structural principles) to an adaptable, open streetlight system. By using the word 'system', we are not referring to an electrical system such as a mini-grid. By system we mean that the design concept itself is understood as ecology of parts, materials, components, tools, power expenditures/generation and carbon.

Deliverables

1. To create a comprehensive kit of parts diagram for the pop up solar streetlight

What materials are needed to make it?
Where to they come form and where do they go to?
What materials are needed to assemble it?
What tools are needed?
What source(s) of power can drive those tools?

2. To **understand and map** the relationships between these parts as **ecology with carbon impacts**

Material Provenance
Material Transport
Product Manufacture
Product Transport
Lifecycle Energy

MIT 4.184 PAPER LIGHT WORKSHOP

Instructor: Prof. S. Kennedy
RA: Huda Jaffer, SELCO
TA: Scott Penman, Smarchs Computation

ASSIGNMENT 1: FLAT TO FORM

This exercise asks students to select three bio-based materials found in the Karnakata State of India: Bamboo, woven Injire (cane), Deal Wood and Cardboard. Students will map the provenance of each material and the present photos or diagrams that show the process by which the material is processed and manufactured. Students will investigate precedents and explore structural principles of bending, deformation, compression and tension. Working in physical model, with basswood or strips of paper at a scale of 3"= 1'-0" please generate a set of designs that can support and accommodate a street lamp, and a solar panel. Please refer to the course Stellar site for the dimensions of the solar panel in the set of CAD drawings that Huda Jaffer has presented.

Problem Statement
Urban infrastructure has historically been funded and managed by municipal agencies and governments as a "top down" project of civil engineering. The implementation of an electrical grid with trenching (excavation for underground conduits) or installation of multiple electrical poles requires political organization and high amounts of capital and roadway transport for heavy equipment.

The very idea of distributed solar street lighting infrastructure brings with it a political dimension. If the 'ownership' model of public street lighting can be organized and implemented by citizen entrepreneurs this create a new delivery and implementation paradigm for the future of solar streetlights. If streetlights can be easily assembled and fabricated mainly on site, or locally in the region, then the costs that would have been incurred in mass production, shipping ad transport can be greatly reduced, leaving only the 'hard' costs of the technology itself. One further IF: If the design can be scaled for a number of different countries and settings, then the cost of the technology itself will also be reduced.

The streetlight you are designing will need to accommodate a **lamp** (which provide the light) a **solar panel**, which provides the power from the sun, and a **battery "box"** for the power electronics, a **structure**, which elevates the lamp to the right height and a **base or foundation,** which keeps the structure upright. As we know, typically these elements are cobbled together in a non-designed manner. Our challenge is to find new and effective ways to integrate these parts through design, using **digital fabrication** and flat to form **assembly techniques**.

Students should question the notion that streetlights must be 'aligned' along the side of the road. This 'street light form' is an idea inherited from the 19th century and the linear trenching in the centralized electrical system. Your solar streetlight designs need not be for a stand-alone object. It might be useful to consider the advantages (structural and spatial) of streetlights that are organized in **pairs or triads** or other geometrical configuration that might help to enhance a new emerging public space of light at night.

It might also be useful to incorporate a 'stealth" program that can expand the uses of the solar streetlight: perhaps the streetlight is designed for an additional use beyond just giving light. It could support a night market stall, or a night school or a community forum or a co-operative, a place where meet to do work. How could these uses drive the design of streetlight, including its base or foundation?

Page 1 of 2
Assignment 1: Deliverables

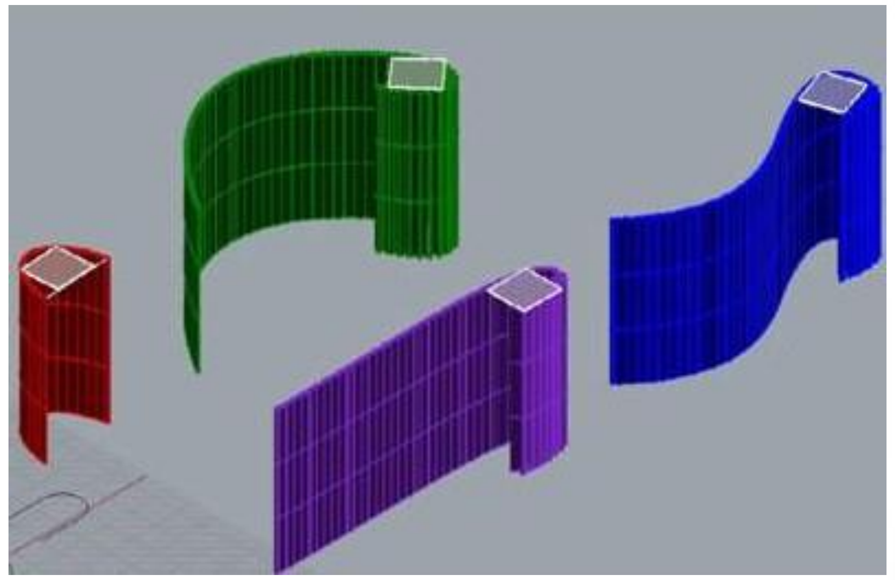
Structure Experimentation & Testing
Our shared goal will be to generate and test a large number of different flat to form design concepts and potential techniques for the street light structure and design. Make simple models first to test how structural forces will behave in your streetlight structure. Allow the material in physical models to give you some force feed back. What experiments can you do, quickly and easily to test/verify your design assumptions?

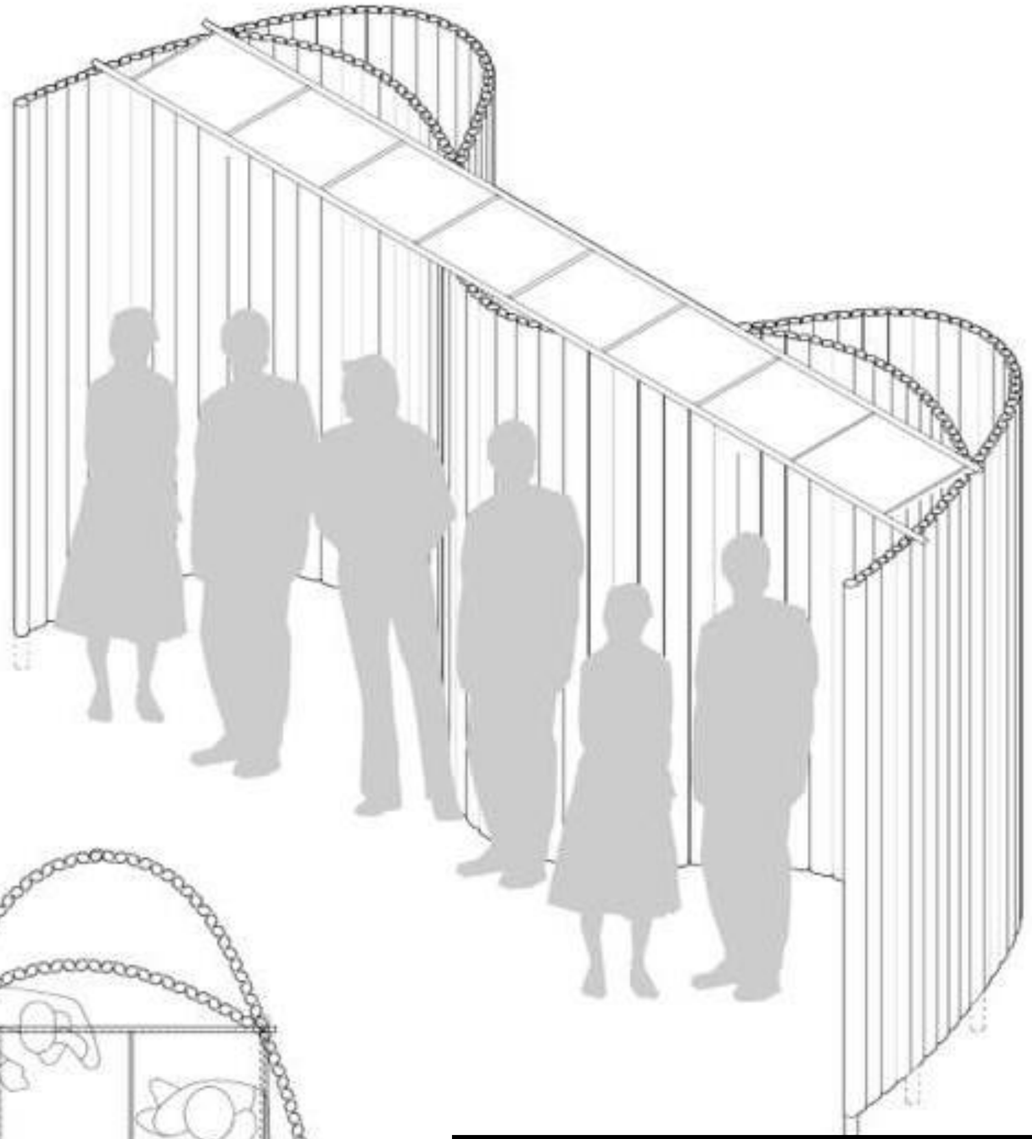
Snapshots from the curriculum outline

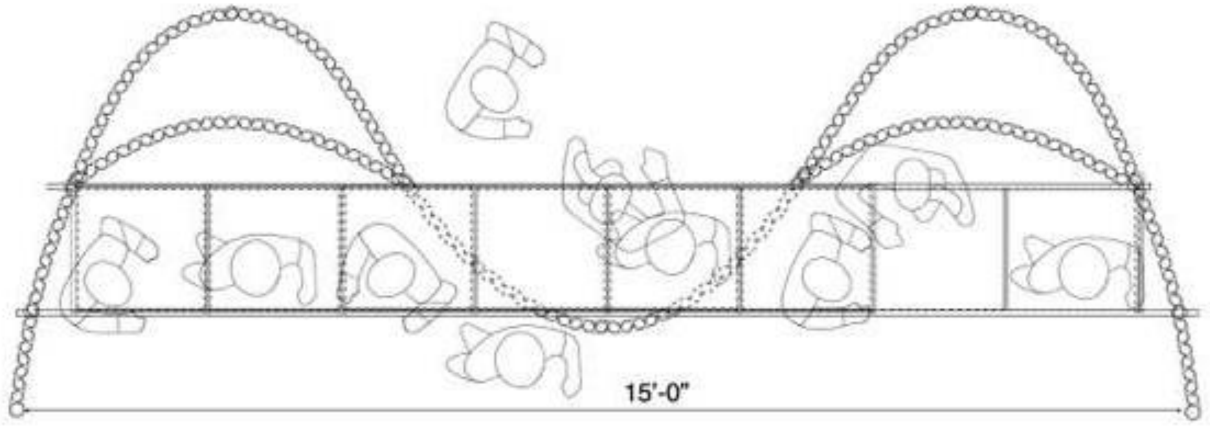
SELCO FOUNDATION

the Lemelson foundation
improving lives through invention

Five inventive concepts developed by MIT student groups include bamboo and areca street light designs and cane portable community lighting designs. Two of chosen innovations from MIT are discussed in the 'chosen designs' section.





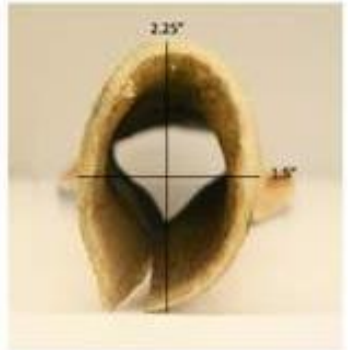


Examples of inventive concepts developed by MIT student groups.

KVA / MIT

- Course work
- Curriculum Building
- **Inventive Concepts**
- Prototyping
- Next Steps

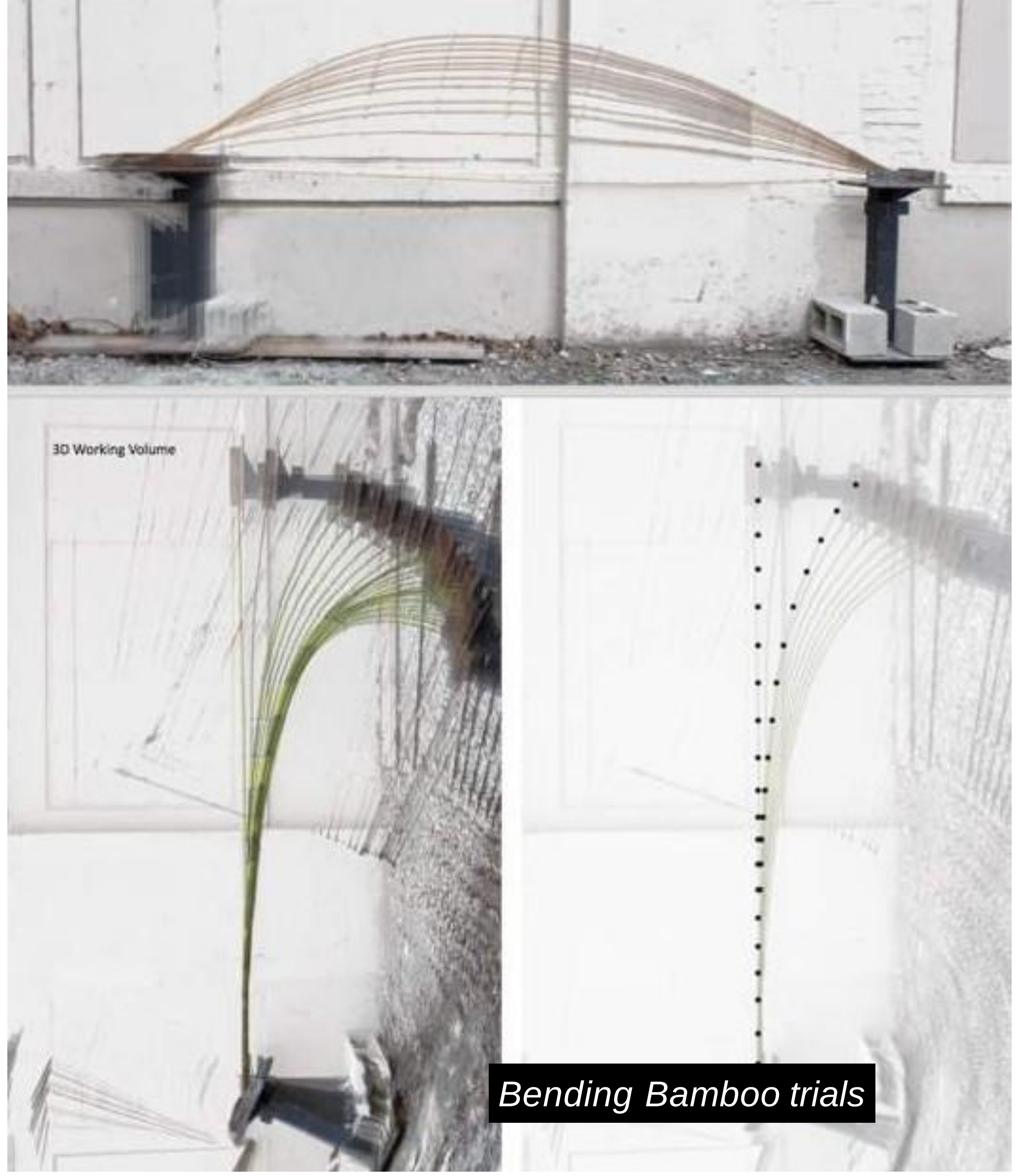
Fan-shaped (Rubber band one end, open on other)



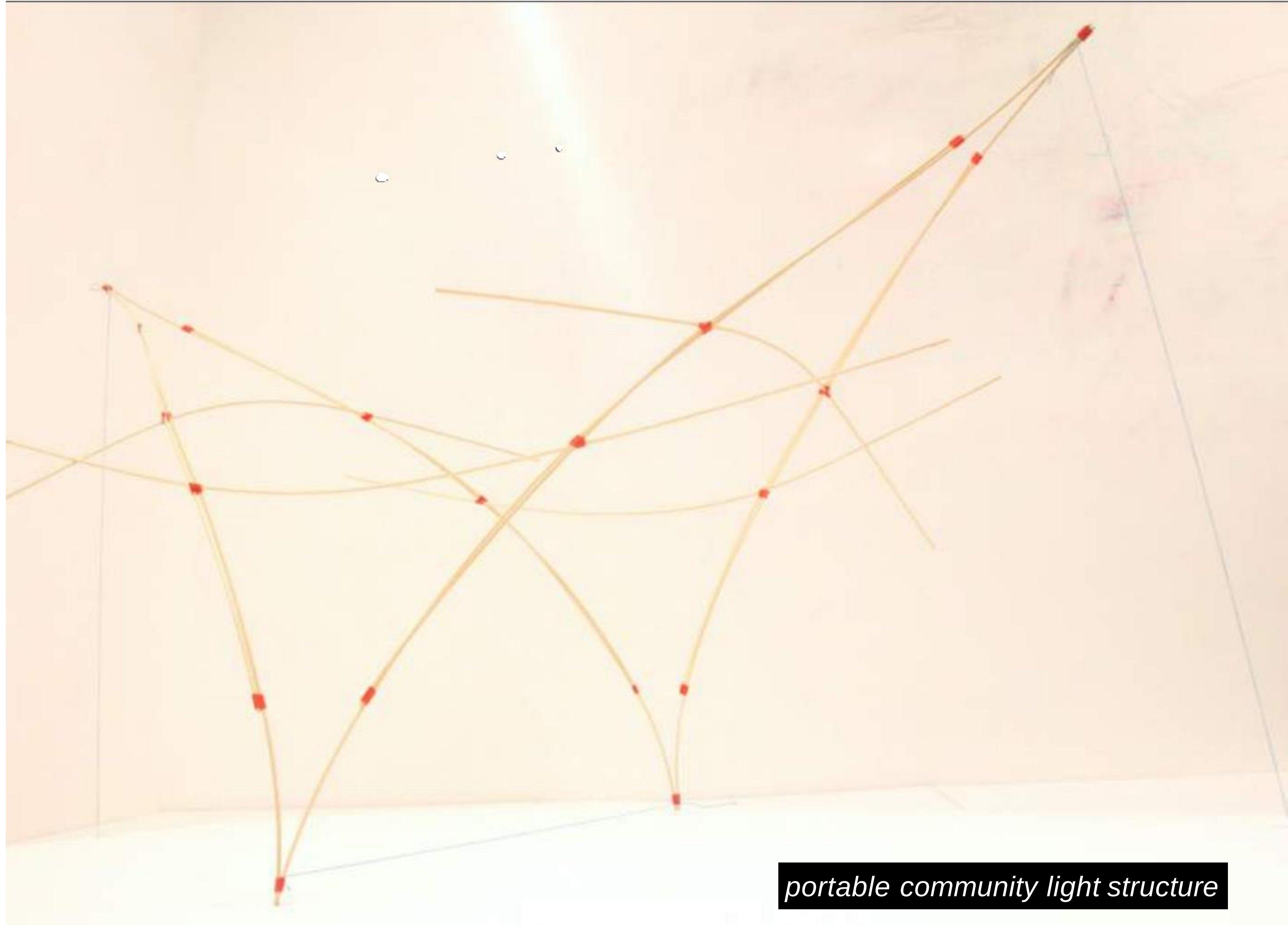
SELCO FOUNDATION

the Lemelson foundation
improving lives through invention

Areca street light concept experimentation



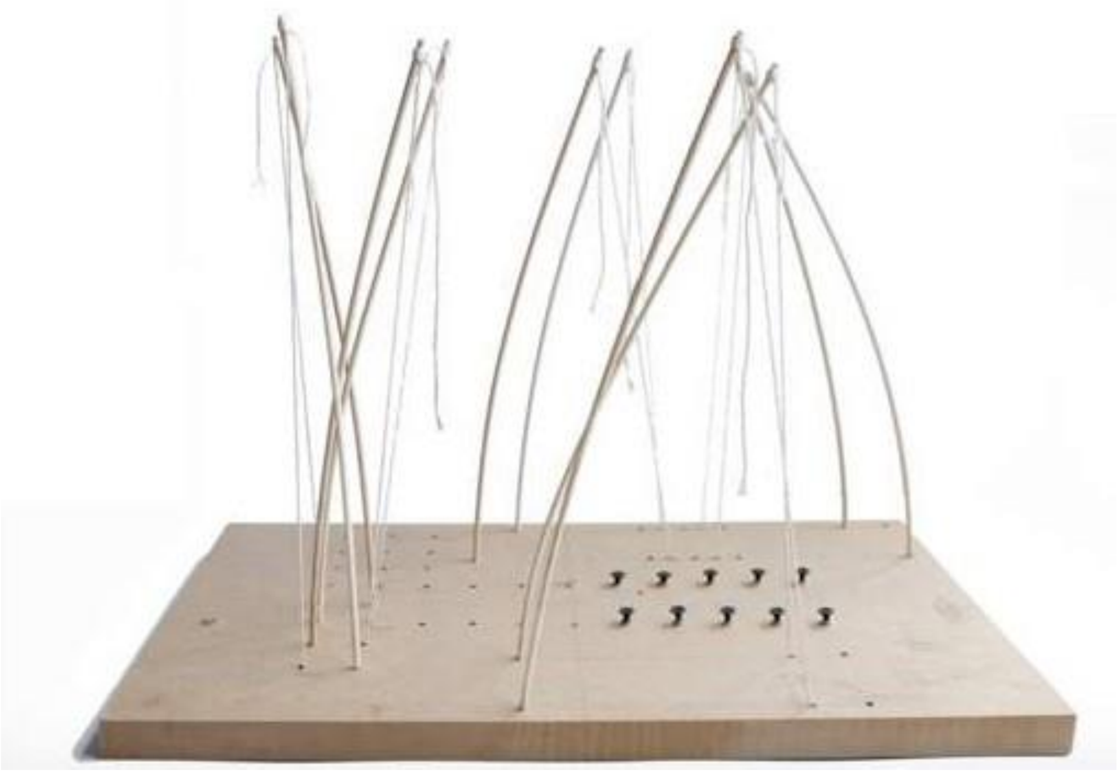
Bending Bamboo trials



portable community light structure

KVA / MIT

- Course work
- Curriculum Building
- Inventive Concepts
- **Prototyping**
- Next Steps



bent bamboo scaled down experiments with adjustable panels

SELCO FOUNDATION

the Lemelson foundation
improving lives through invention

Post the MIT spring course, SELCO Foundation continued to work with KVA material exploration along with interns from MIT and Harvard.

Over 20 prototypes were developed among which the major prototypes included concepts shown along side made from:

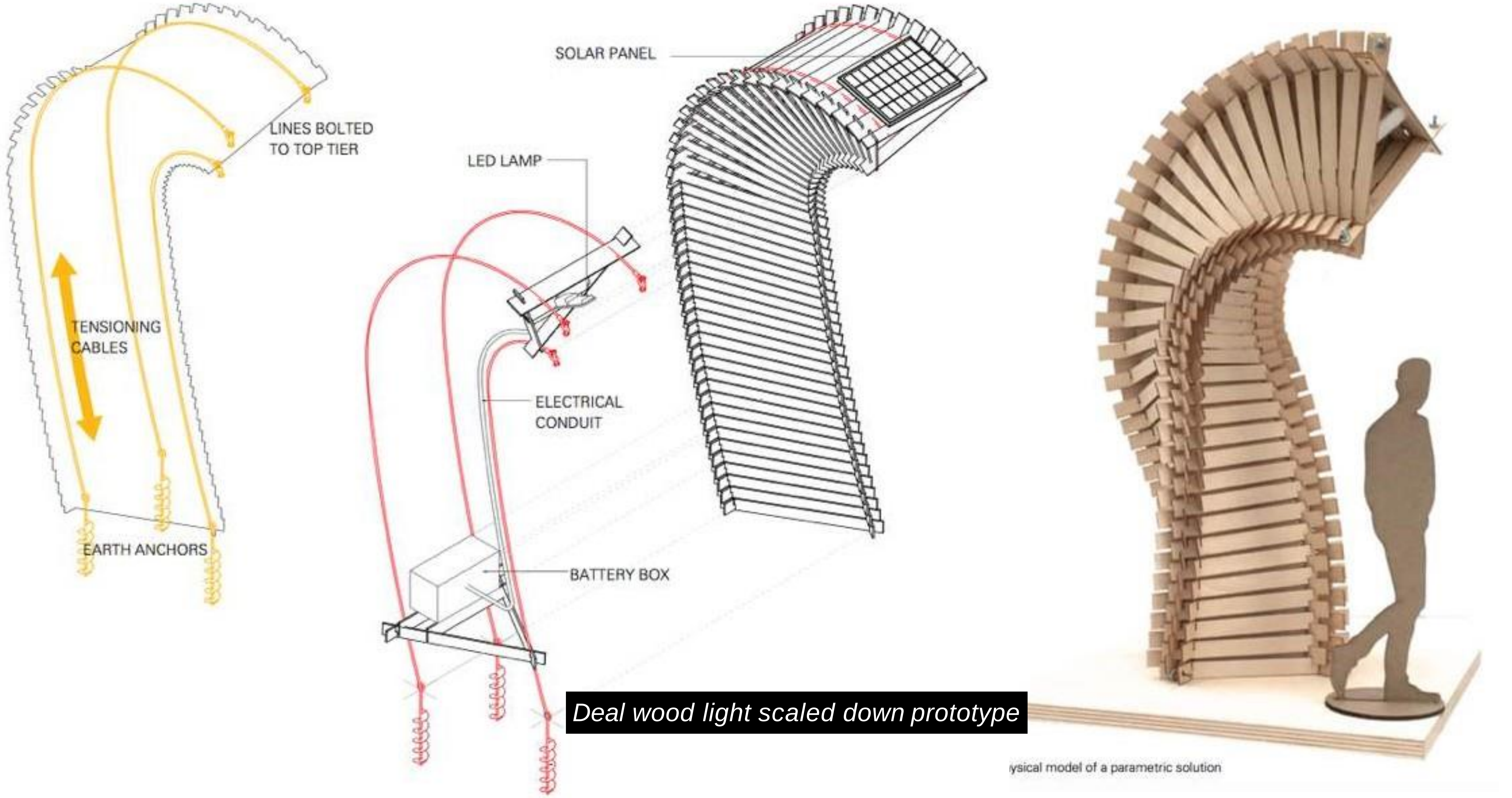
Bamboo

Areca

Deal Wood

Paper/ Card Board

This work was taken forward from the students that took the course up in the spring semester. Two chosen designs after the summer internship inventing green activity are being further refined and piloted on site.



Deal wood light scaled down prototype

KVA / MIT

- Course work
- Curriculum Building
- Inventive Concepts
- Prototyping
- **Next Steps**

Areca light full size prototypes

SELCO FOUNDATION

the Lemelson foundation
improving lives through invention

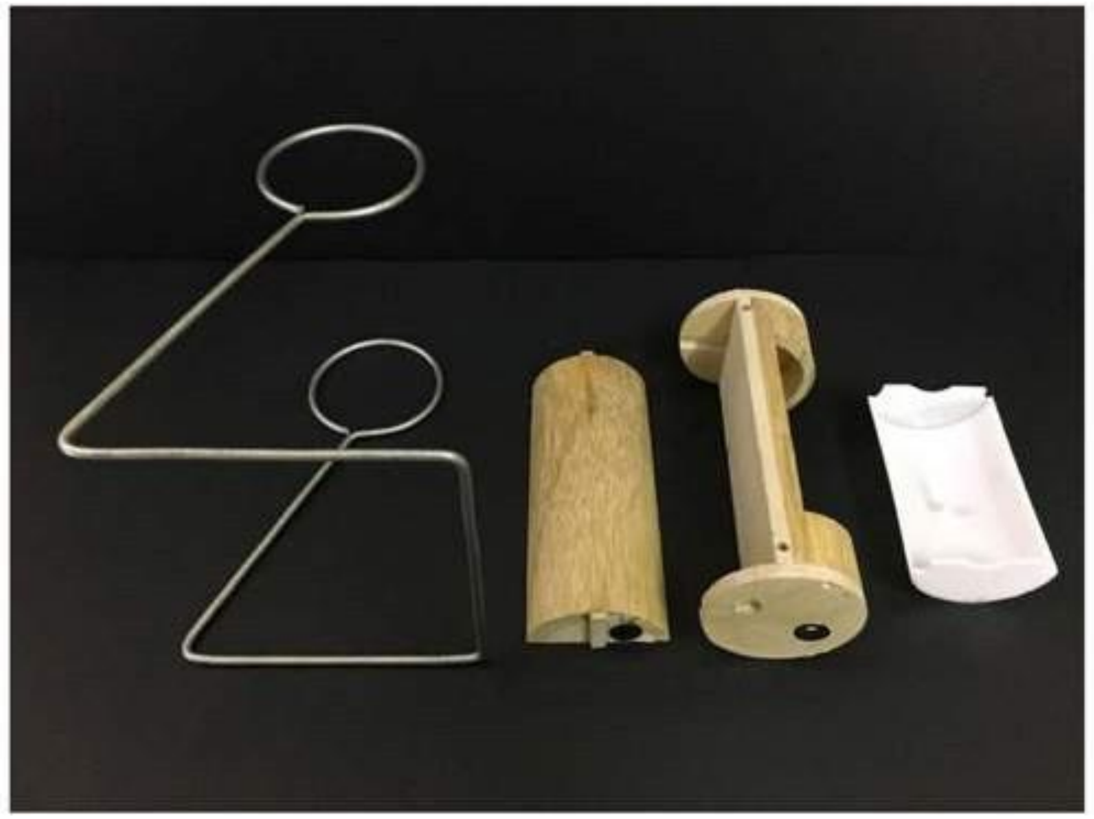
Chosen Innovations Srishti

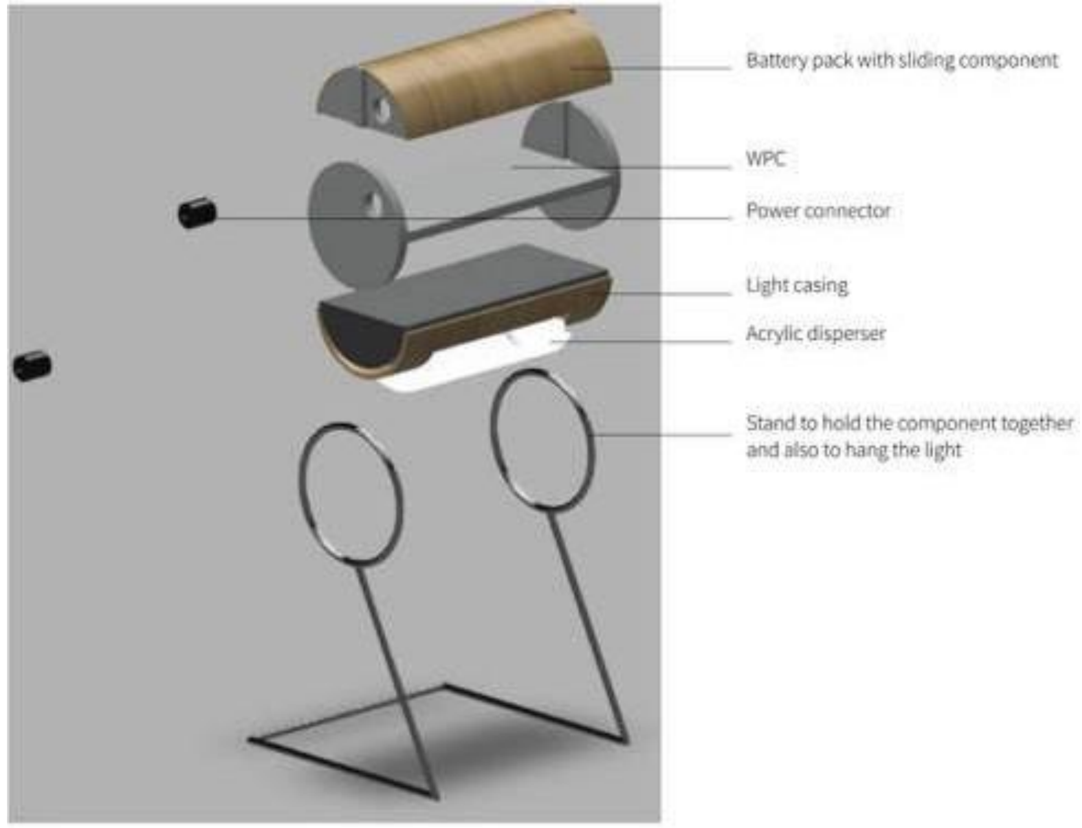
Design 1: Chennapatna portable light (Wooden Lac lathe toys). A traditional Indian art from that produces wooden toys using a manual lathe and natural lacquer for color is a dwindling form of art, with entrepreneurs loosing livelihoods and becoming laborers. This portable light design uses the locally found material paired with the art form to produce a potential low carbon portable light. It is designed to be used in multiple ways such that it can suffice different user needs.

Design 2: Bamboo portable light.
Designed to be built with bamboo and minimal steel. This low carbon light replicates an existing portable light design.

Wooden Lac Light concept

OUTCOMES





Stand on shelves or floor

Hang it from the poles of housing structure

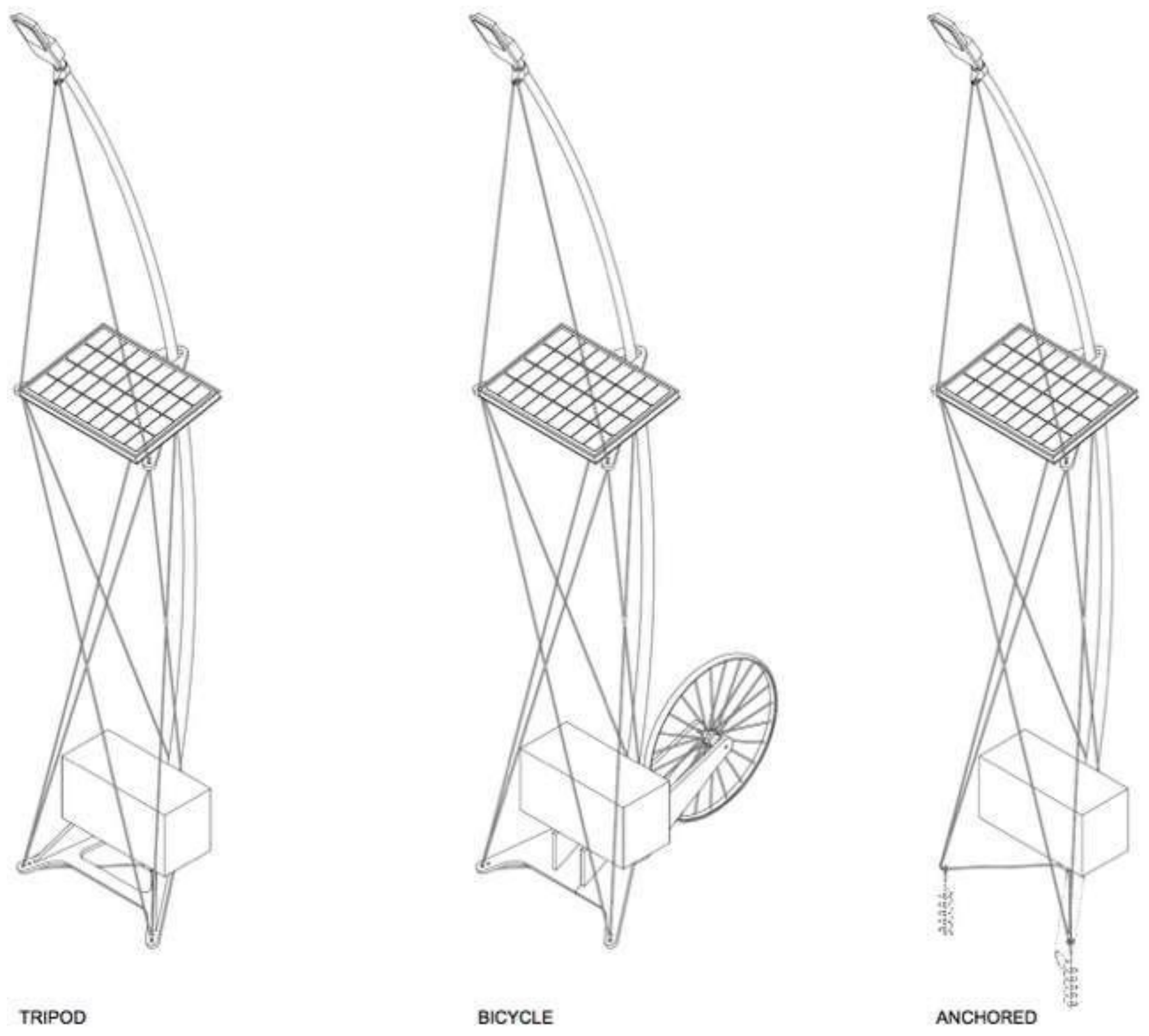
Bamboo Portable Light concept

Portable light

Chosen Innovations KVA

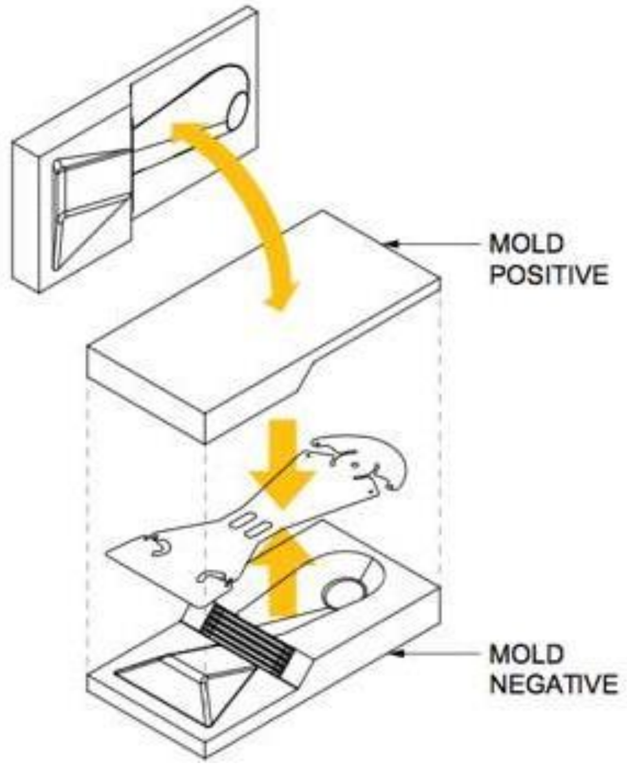
Design 1: Bamboo Street Light
Bent Bamboo street lights which are installed using the tension between string and bamboo- these lights are designed with 3 variants temporary, portable and fixed (grouted) variants. The lights are designed in a way that tremendously reduces costs and efforts in packaging, transportation and installation. The invention lies in the contraption that is used to grow the bamboo in a bent form which increases the strength of the system.

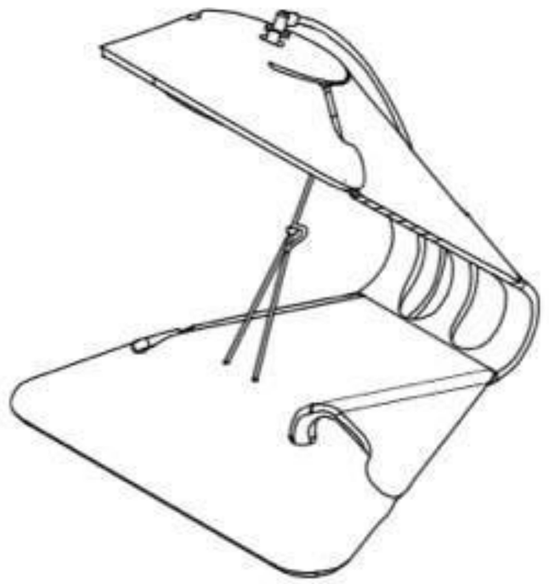
Design 2: Areca Study Light
Designed to be built locally using cold molding process, drastically bringing down the embodied energy and improving local livelihoods.

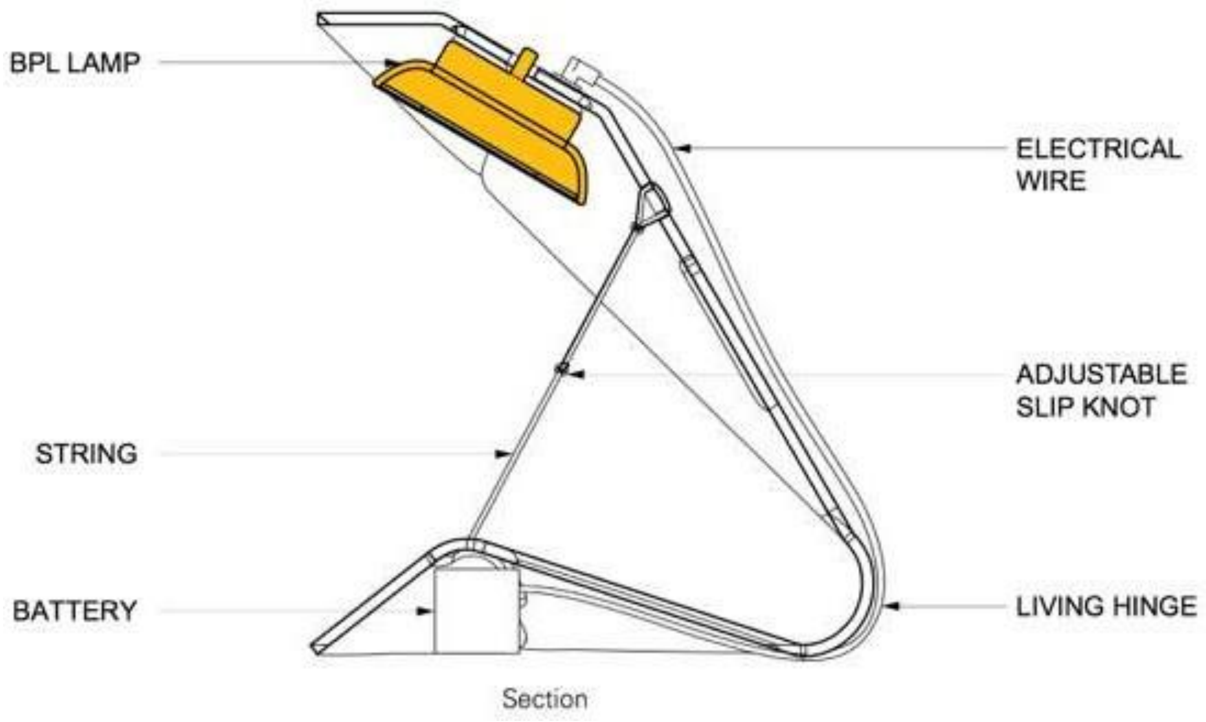


Bent Bamboo Street Light concept

OUTCOMES







Areca Study Light comcept

Direct Project Deliverables

Type of outcome	No	Details
No. of universities	2	Srishti (6 months course run), MIT (4 months course run + 3 month summer intern project with KVA) -ongoing discussion to replicate both courses next year
No. of Faculty	4	Sudipto, Nandini and Ravi from Srishti and Sheila from MIT (who is also the principal architect at KVA)
No. of students	17	8 from Srishti, 6 from MIT and 3 interns at KVA
Curriculum development	2	Both curriculums developed will be further refined and eventually merged into one curriculum
No. of product inventions	3	Using Chanapatna toy skill for lighting, using cold modeling process for areca, using contraptions to grow street light bamboo forests. (all currently in the next pilot phase)
No. of product innovations	15	multiple- covered in the documentation (4 being taken forward)
No. of implementation models	3	covered in documentation
No. of prototypes	>70	across India and Boston
No. of pilots	4	currently in progress

OUTCOMES

Learnings

Student Learnings	Course Learnings	General Learnings
- Material exploration requires a lot more risk taking - Using resin in materials increases the embodied energy - Most high carbon decisions are often low cost decisions which are difficult to overcome - Lenses of practicality and feasibility can be thought out at a later stage during iteration	- Giving a more focused and concise brief can improve chances of innovation/ invention (for example instead of choosing any light keep it focused to which one and why) - Give more time for understanding natural/ local materials and current supply chains. - More clarity is required in each theme and topic as the themes are very wide, themes can also be split.	- Partnerships with university requires at least one years time in planning - logistics and permissions need a minimum of six months of buffer time - Each faculty has their own style of teaching and accommodating flexibility, the outline should take individual types and preferences into account and not mandate strict syllabus

CONCLUSION

Each of the final designs pushes the boundary of distributed manufacturing and sustainable design. Moreover if implemented the impacts will include
> reduced environmental impact (carbon neutral products)
> positive life cycle assessment
> local livelihood generation
> decreasing costs and efforts on production, packaging, transportation, distribution and end of life

The impacts of the course / curriculum include
> an integrated and collaborative learning process for students
> exposure to themes of sustainability and decentralization
> hands on experimentation and innovation with new and natural materials