Curriculum Development for the WPI MS4SSA Modules: From Materials Science and Engineering to Robotics and Project-Based Learning

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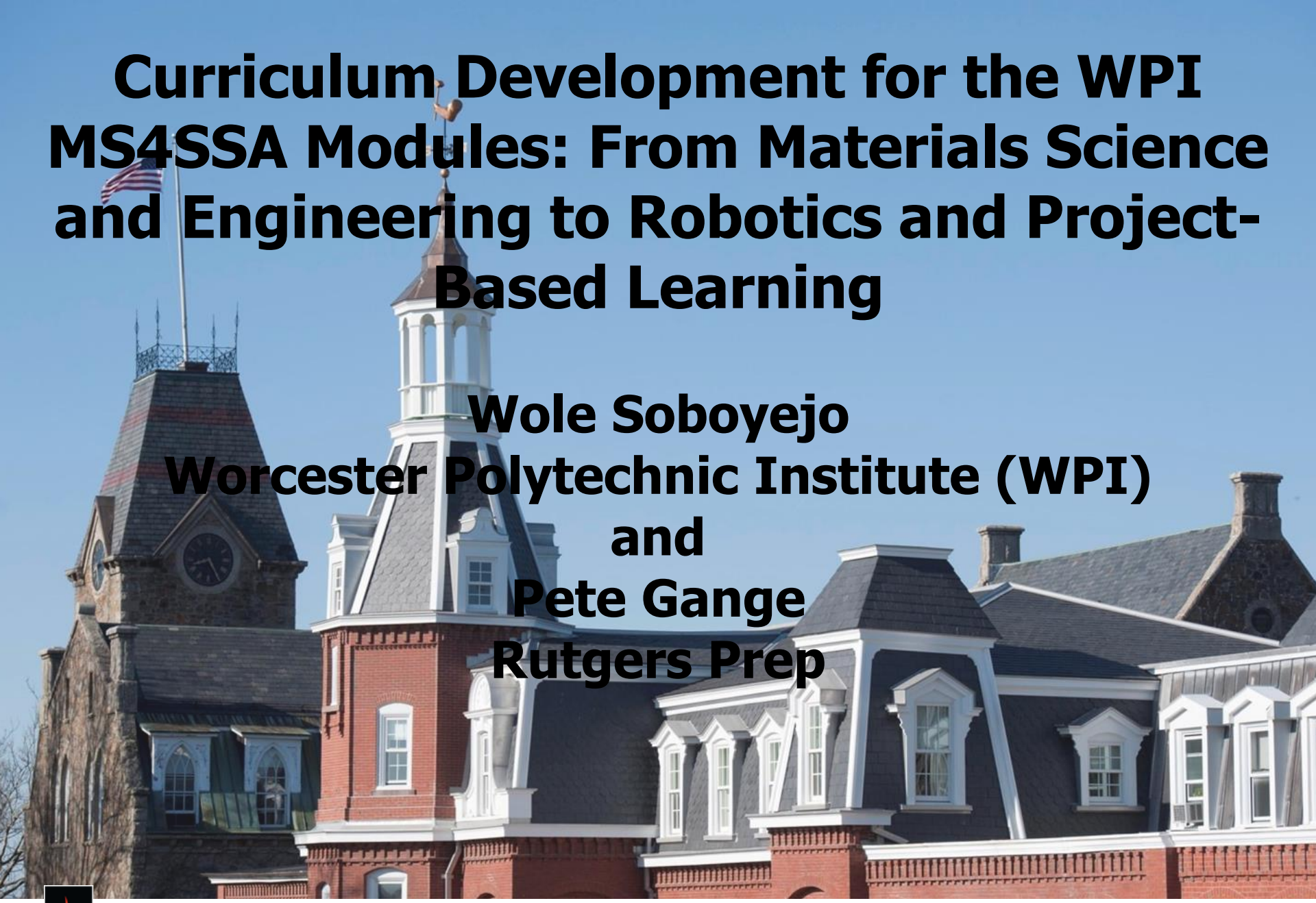
Rutgers Prep



NEW JERSEY CENTER FOR TEACHING & LEARNING

WPI

THE WORLD BANK

WPI Approach to Theory and Practice

MS4SSA
Math and Science for Sub-Saharan Africa

- WPI's approach to learning involves a combination of theory and practice
- This is relevant to the development of a pipeline of Africans in STEM fields
- Need strong foundation in math and science – necessary but not sufficient condition
- However we also need a strong culture of problem solving, creativity, tinkering, creativity and team work informed by global best practices
- African Governments
  - Gambia, Ghana, Guinea, Ethiopia, Zanzibar, Lesotho, Malawi, Mauritius, Mozambique, Nigeria, Rwanda, Burkina Faso, Benin, Senegal, Togo, Niger, Mauritania
- Participating Institutions and Collaborators
  - From Africa, Japan, India, China and the United States

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Initial WPI Modules: Building a Culture of S&T in Africa

MS4SSA
Math and Science for Sub-Saharan Africa

- WPI has a rich culture of STEM outreach and project-based learning that can inform the development of modules for African countries and regional nodes
- WPI modules focus on building a culture of S&T and digital content/pedagogy that can be scaled
  - Materials science and engineering modules
  - Robotics modules
  - Project-Based Learning (PBL)

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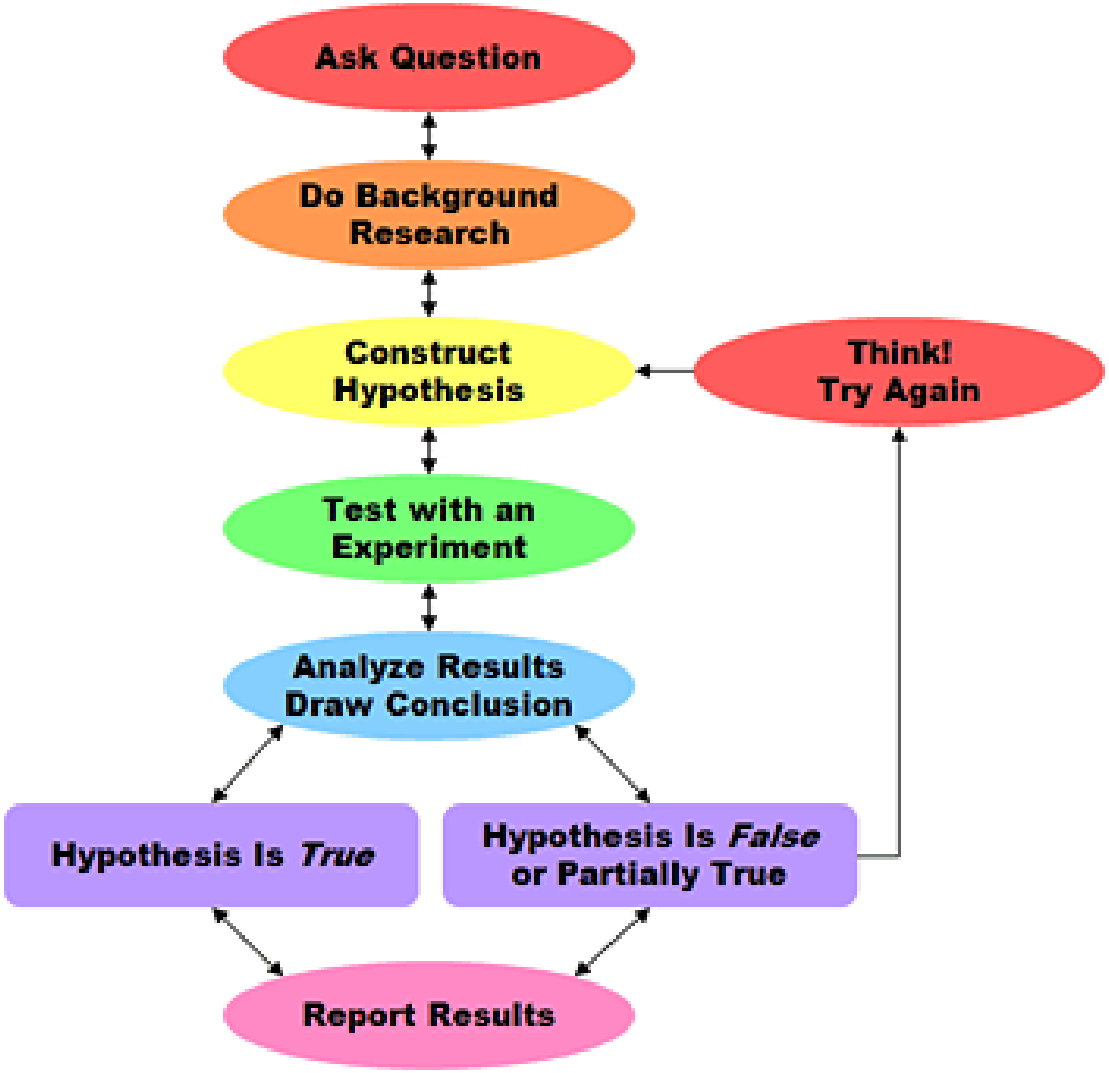
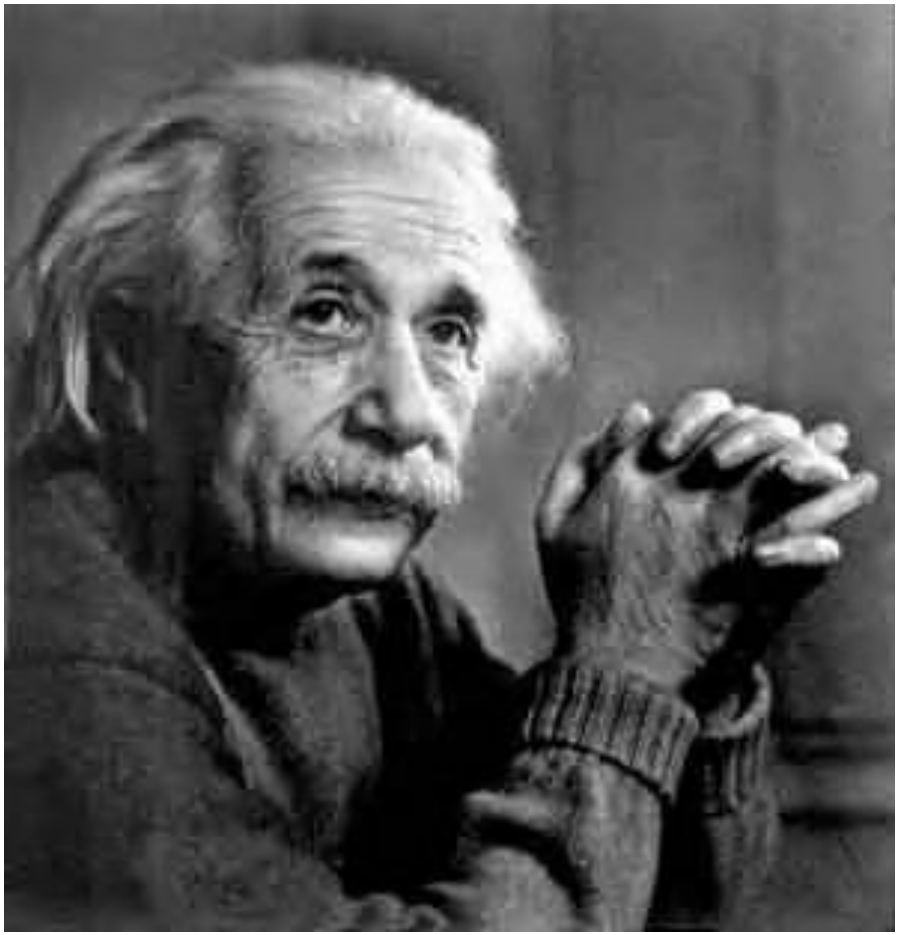
Scientific Method



Lab: Scientific Method

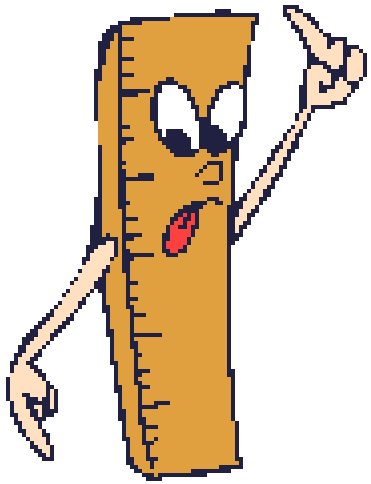


Lab: Scientific Method

In this experiment, you will first make a "hypothesis".

Can you accurately calculate the height of an individual if you know their forearm length?

Lab: Scientific Method



Measure and record the length of each subject's forearm.

Measure and record the height of each subject.

Lab: Scientific Method

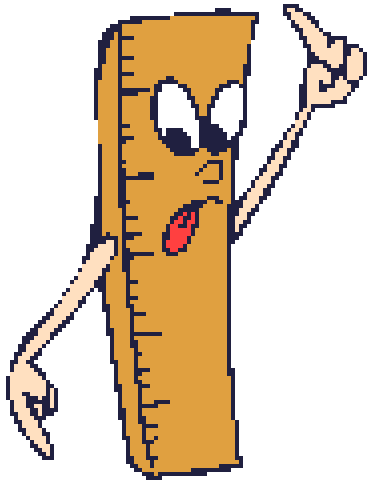
Data Chart

Forearm Length (m)	Height (m)

Lab: Scientific Method

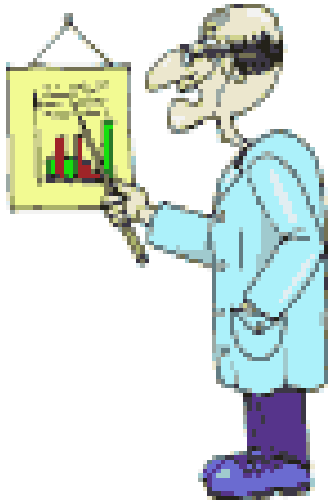
Make a graph plotting forearm length vs. height.

Lab: Scientific Method



Measure and record the length of your teacher's forearm.

Lab: Scientific Method

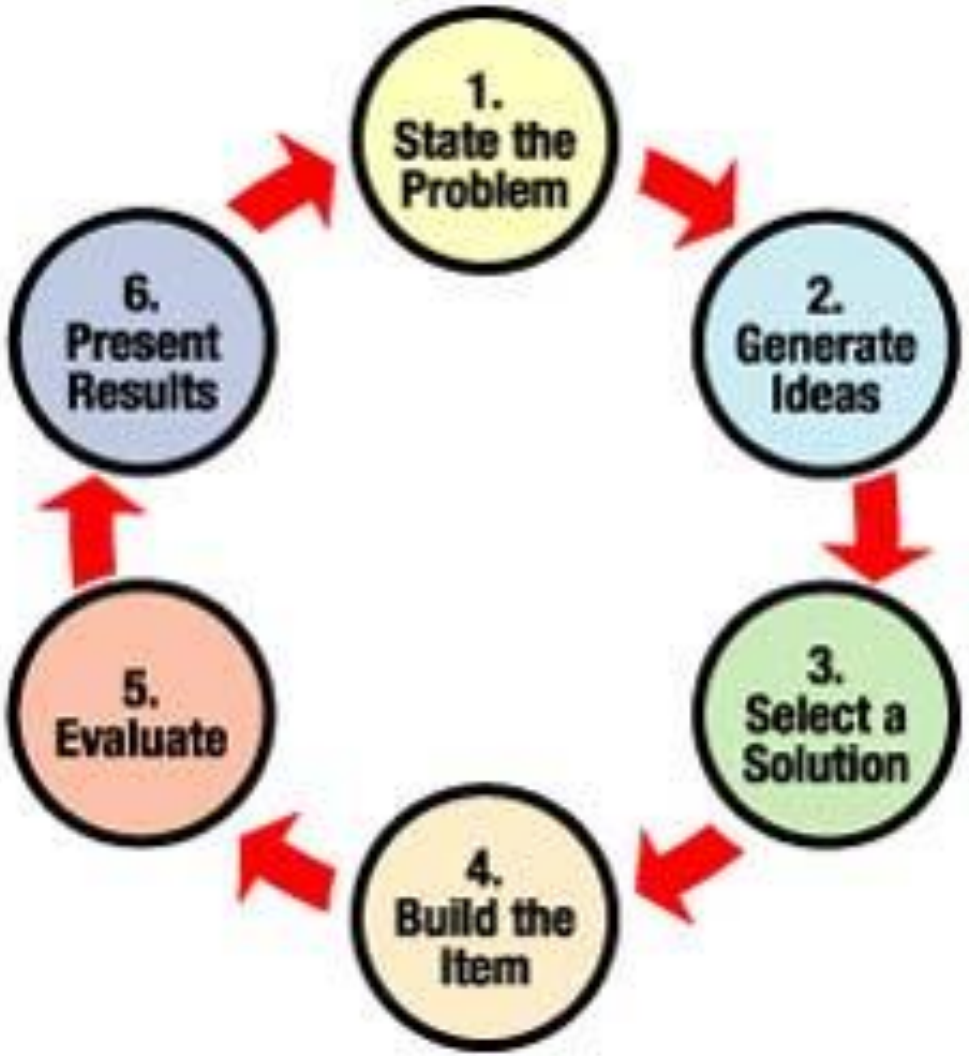


Using your graph, predict the teacher's height.

Test your hypothesis by measuring your teacher's height.

What is the Engineering Process?

Engineering Process



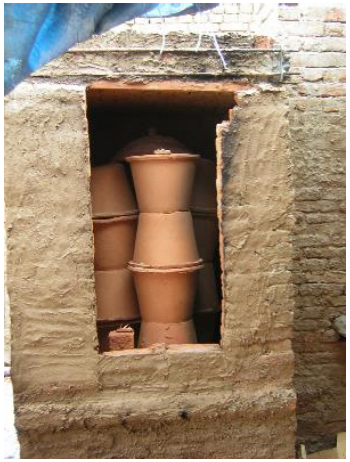
In the engineering process, a prototype is designed and constructed

The prototype is tested, refined and retested until the problem has been solved

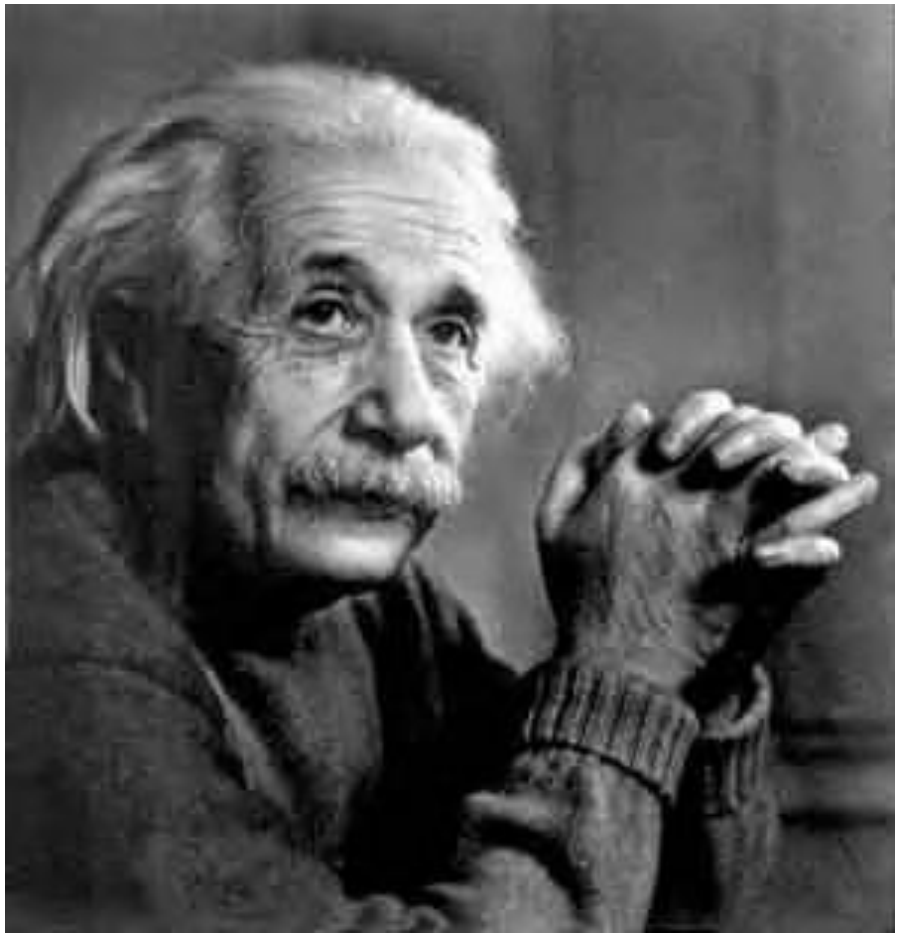
Filter Processing - From Ideas to Markets







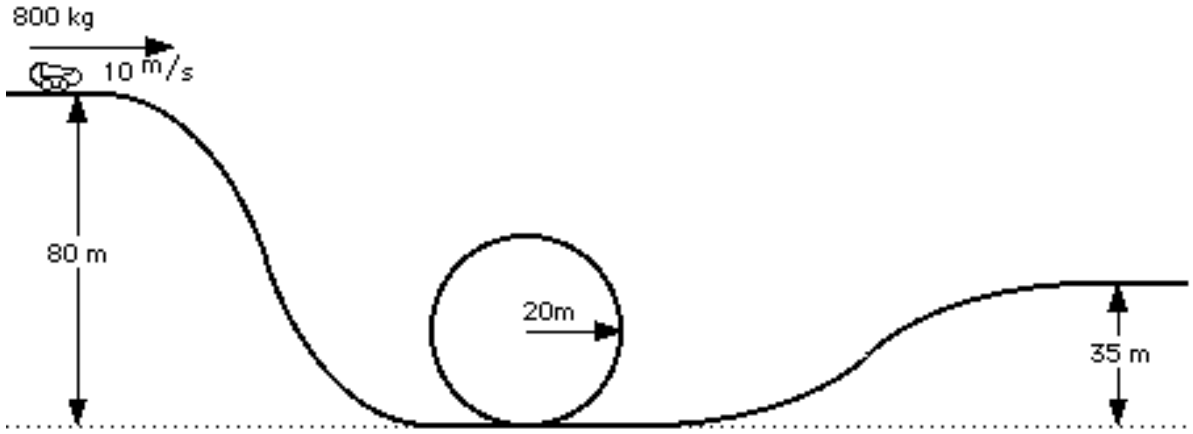
Lab: Engineering Process



In this lab, you will design and construct and test a "roller coaster"

The only materials you may use is a piece of rubber tubing and a ball bearing.

Lab: Engineering Process



Using just your rubber tubing, construct a roller coaster!

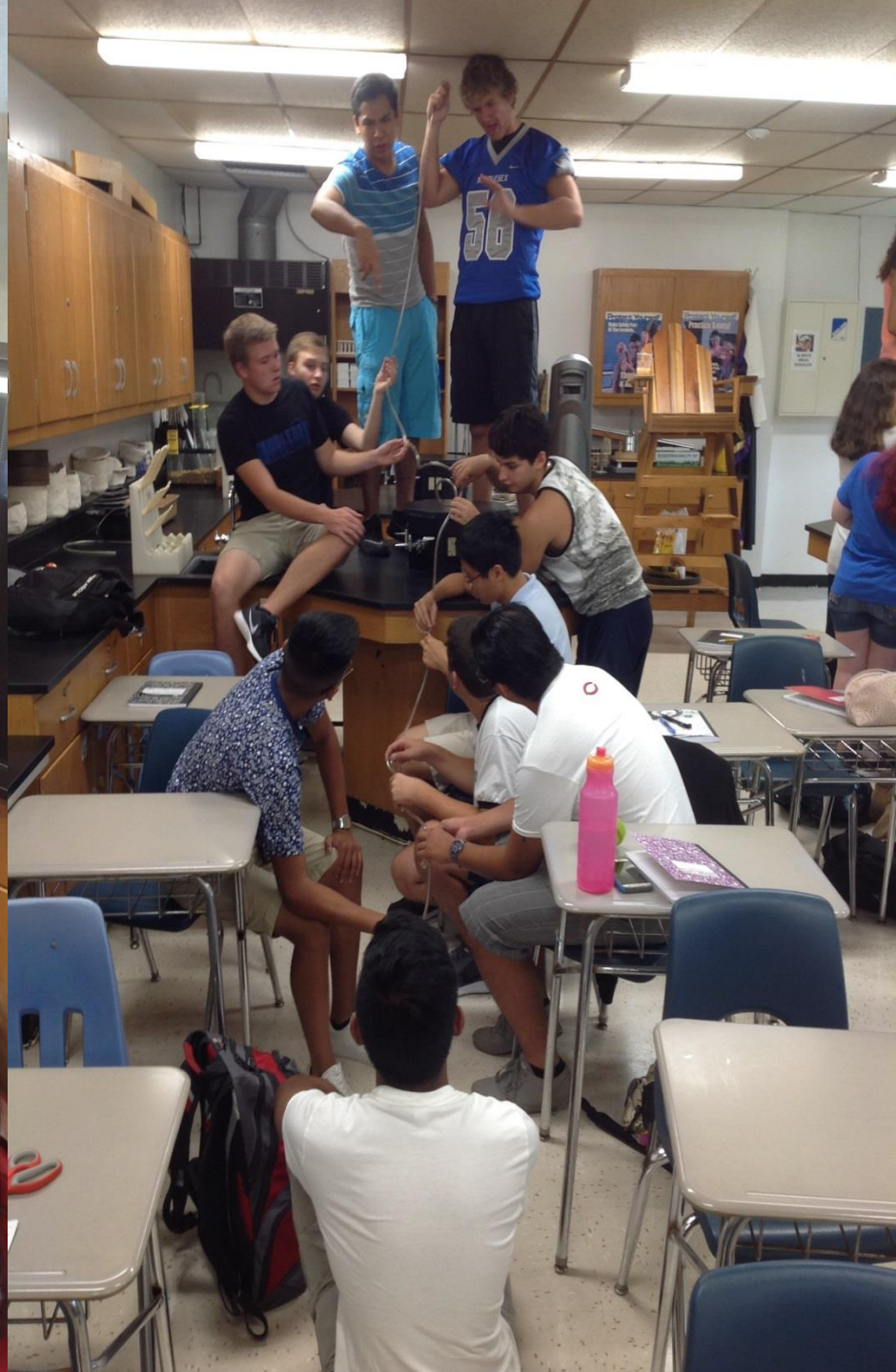
The ball bearing must complete the whole course!

Scoring: Each vertical loop (360˚) = 10 Points!

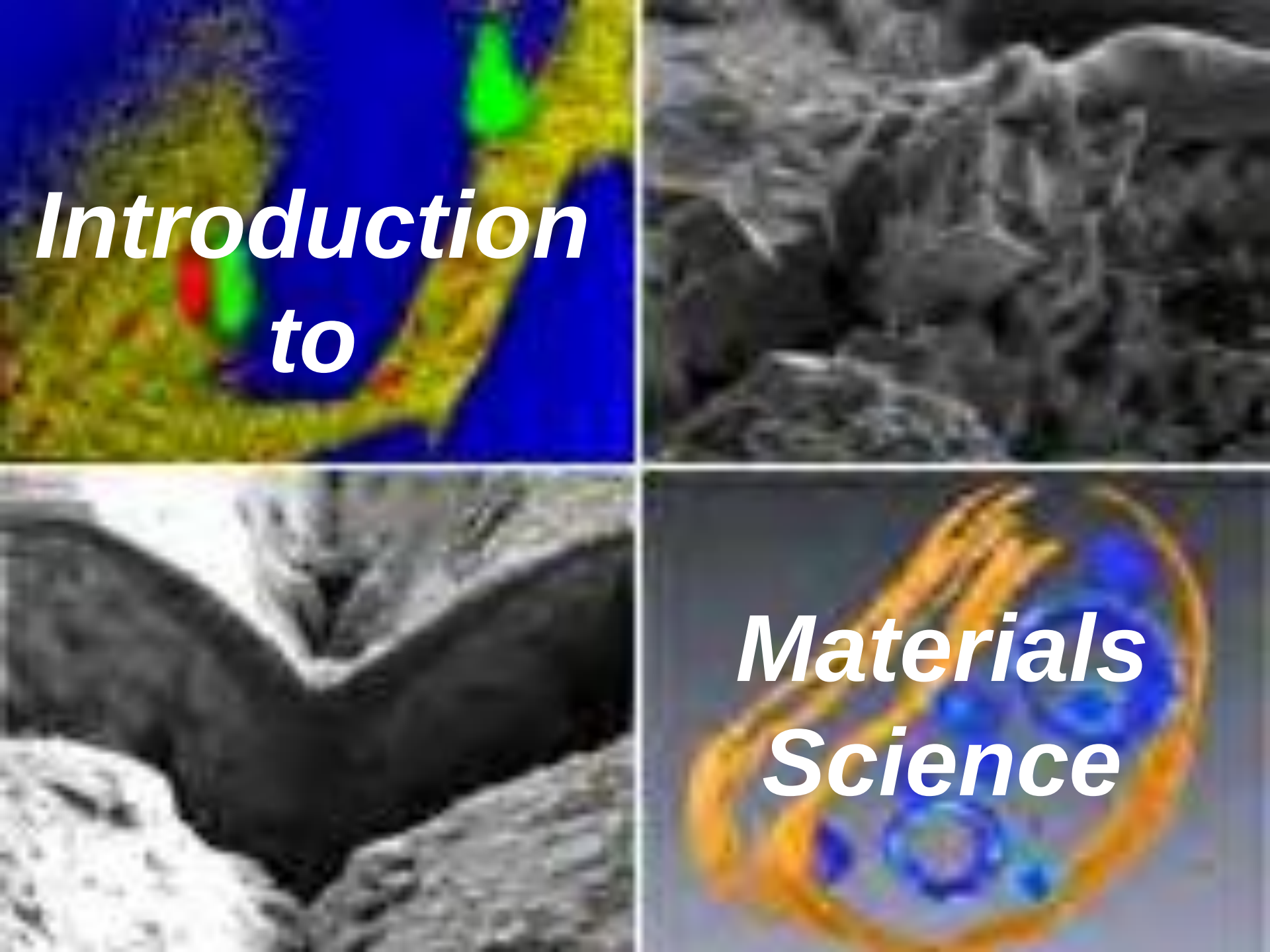
You may try as often as you like, best score counts!

Failure is just a reason to start over more intelligently!

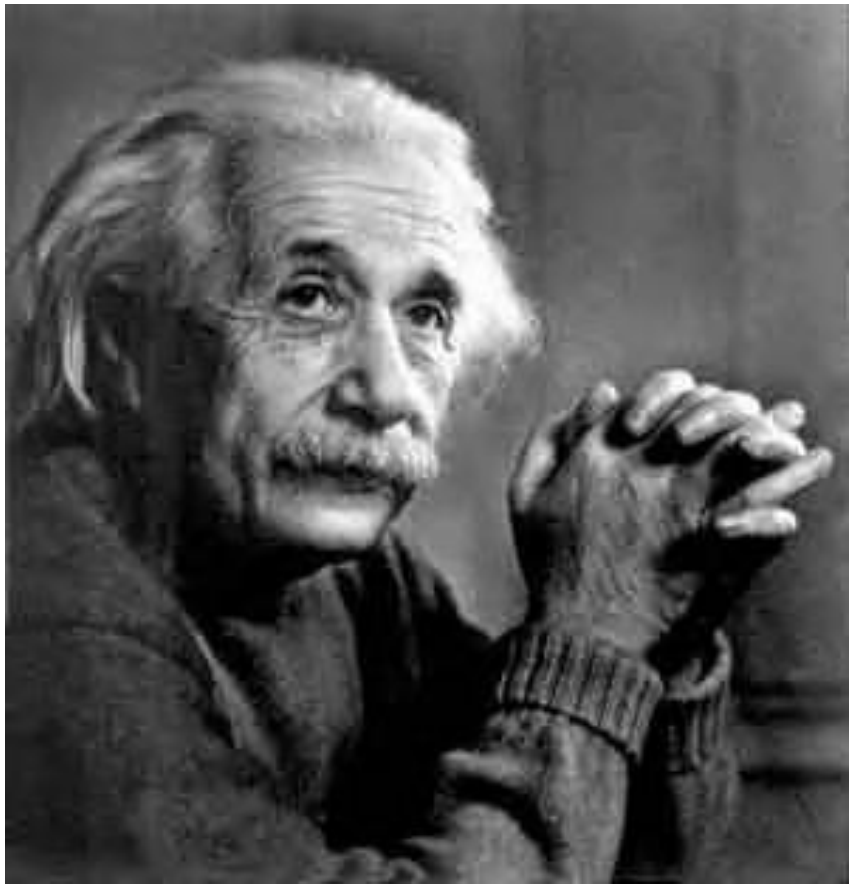

MIDDLESEX



In real life problem solving situations, scientists often do some "engineering" work while engineers frequently apply the Scientific Method!

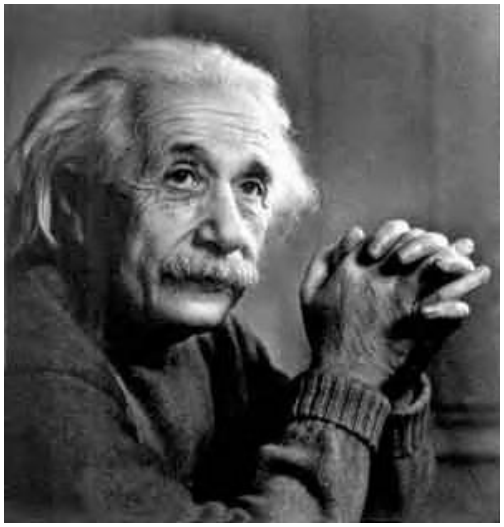

Introduction
to
Materials
Science

What is Materials Science?



The Study of Stuff !

Why Learn Materials Science in Africa?



Africa is the richest continent in terms of mineral deposits in the world!

From Artisanal Mining to Wealth

- **Africa has a rich array of minerals and materials resources**
- **Artisanal Mining (Small-Scale)**
  - Difficult conditions
  - Limited profits
- **Industry (Mid- to Large-Scale)**
  - Africa's richest man (Aliko Dangote) manufactures cement from African raw materials
  - Value addition to people, minerals and natural products

Materials – The Major Driver

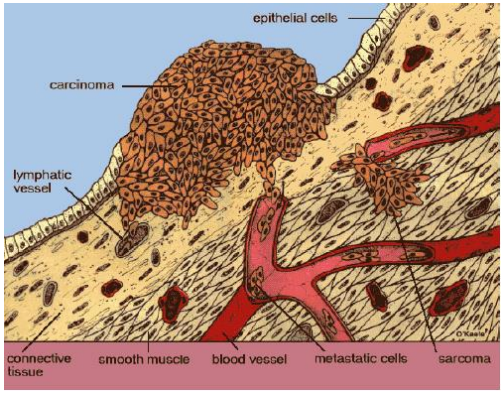
- Science and technology are the major engines of development
- Materials have always been a major driver in technological change…
  - Alloys
  - Semiconductors
  - Polymers
  - …

Hard materials

Soft materials

Materials and Project-Based Approach

- **Advanced Materials (Bio and Nano)**
  - Targeting of disease
  - Alternative energy
- **Societal Development**
  - Affordable infrastructure e.g. recycling of agricultural & industrial waste
  - Value addition to people, minerals a natural products



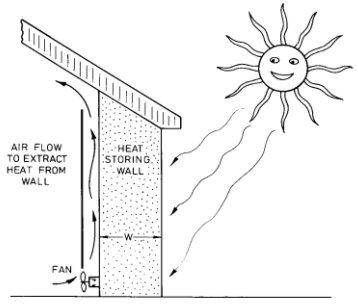
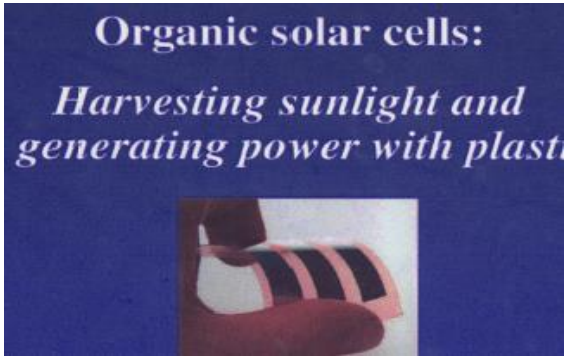


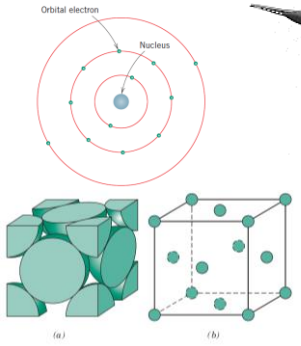
FIG. 6.32 A heat-storing wall. The sun shines on the outside during the day; heat is extracted from the inside at night. The heat diffusion time through the wall must be about 12 hours.

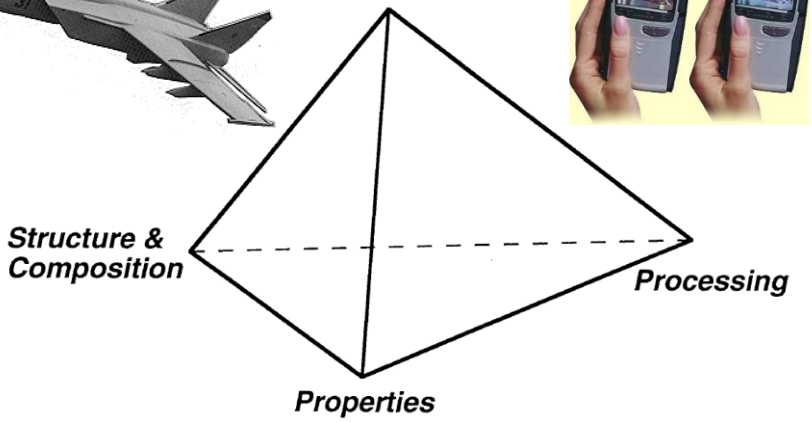


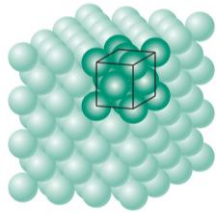
Materials Science and Engineering

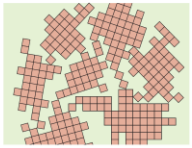
MS4SSA
Math and Science for Sub-Saharan Africa

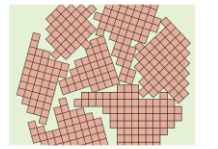
- Science: Knowledge-driven exploration of materials
- Engineering: Application-driven development of materials

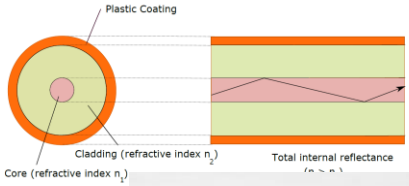


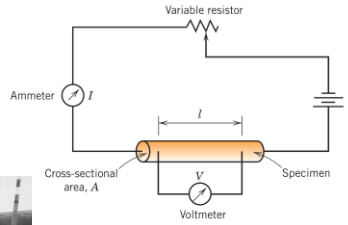


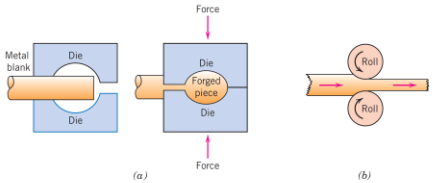


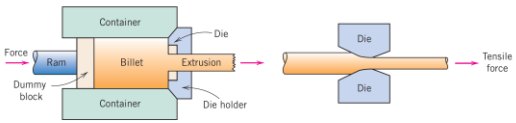




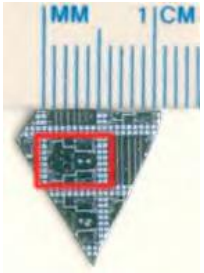


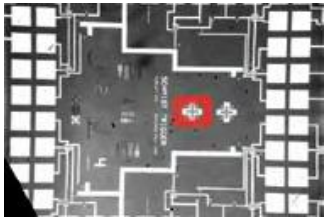


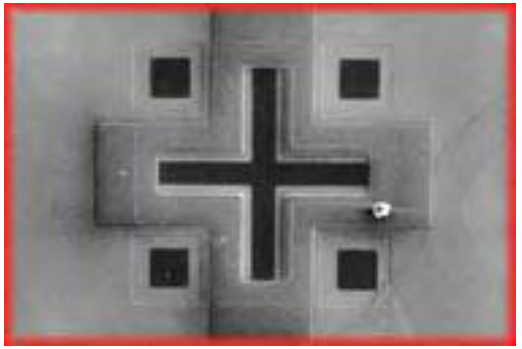




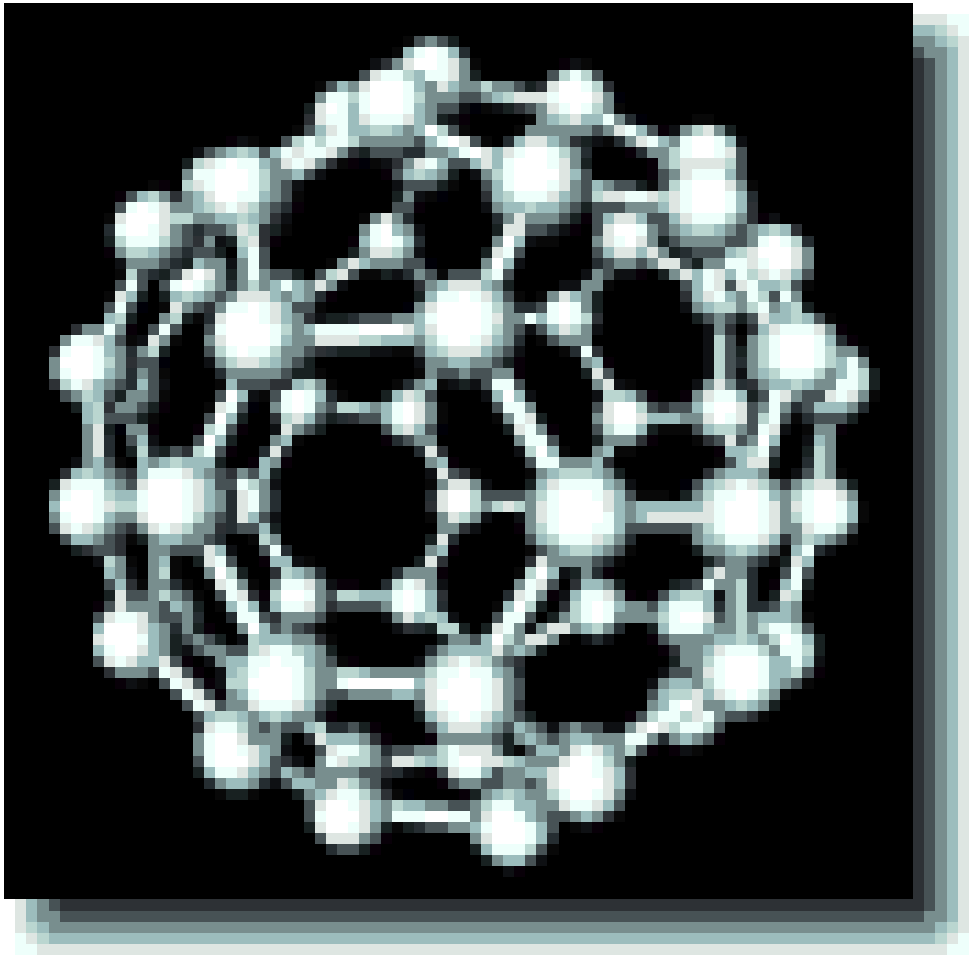
You Understand What You See





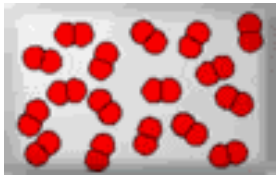


Material Structure

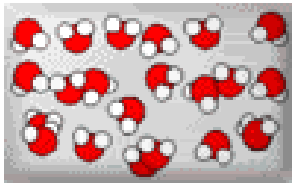


Types of Matter

Pure Substances

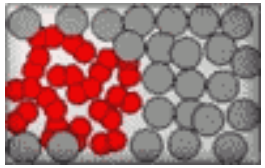


Elements

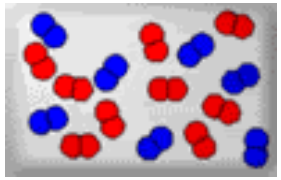


Compounds

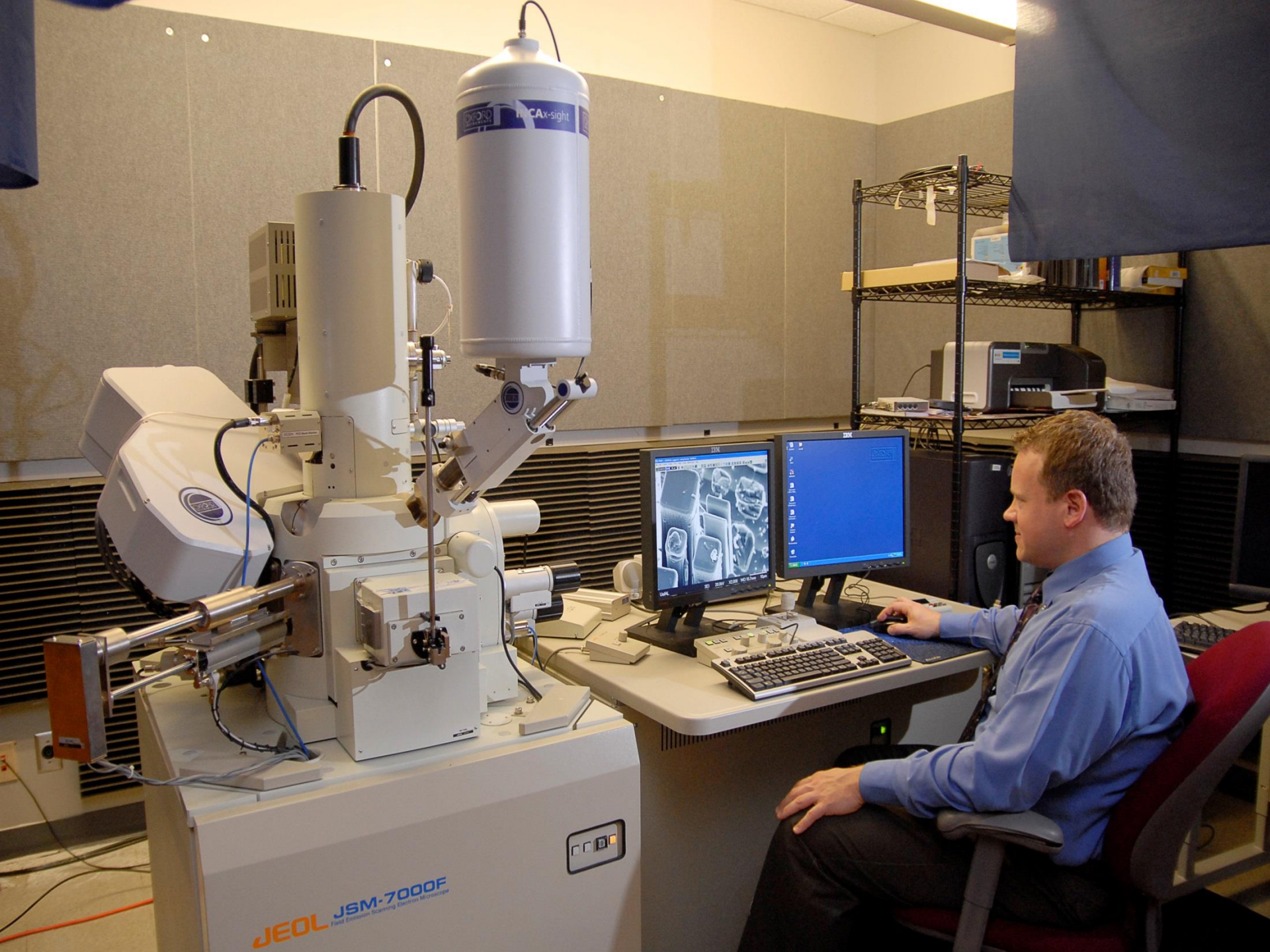
Mixtures



Heterogeneous

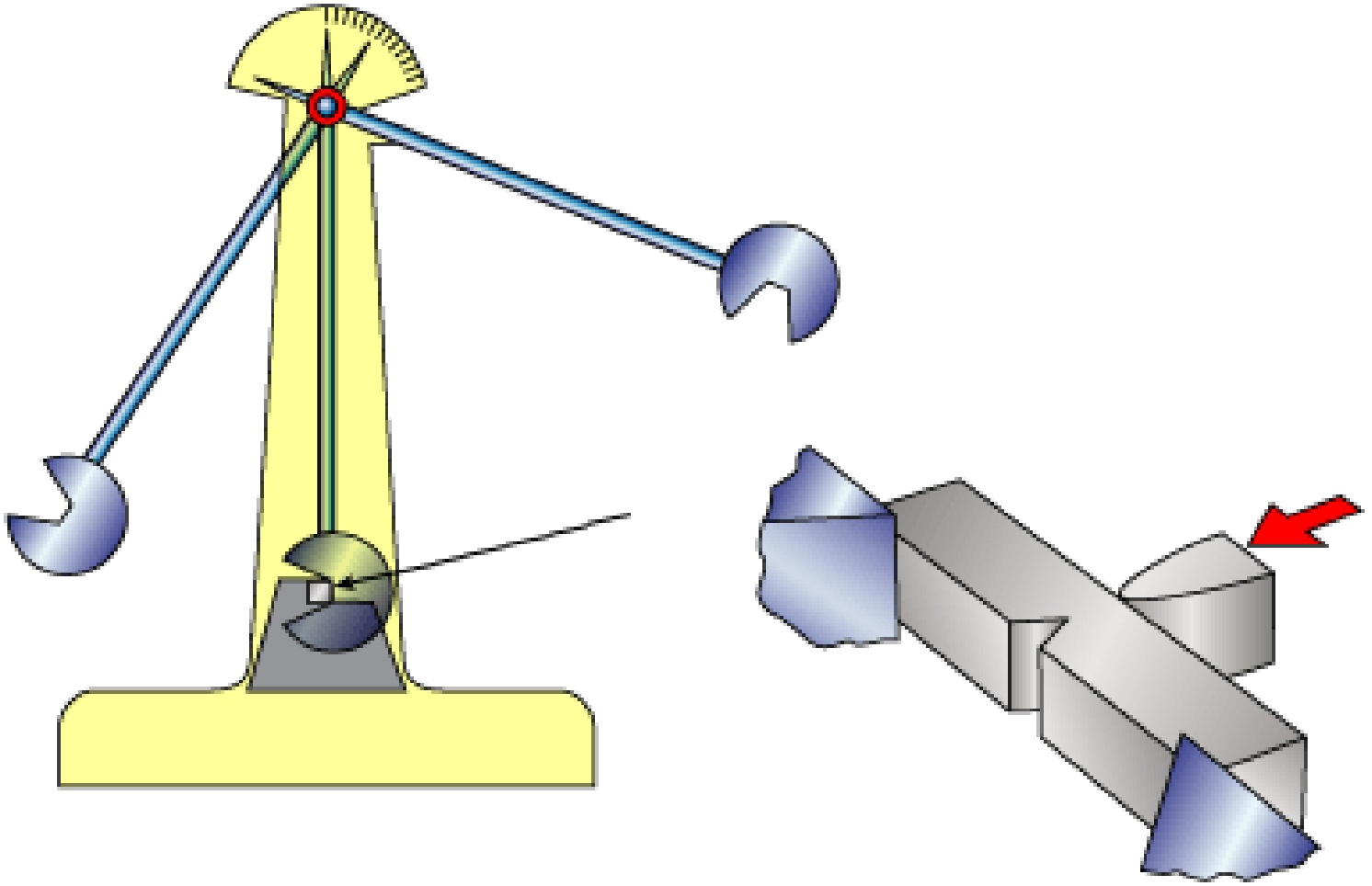


Homogeneous


INCAx-sight
JEOL JSM-7000F
Field Emission Scanning Electron Microscope

Material Failure

Material Failure



Improving Energy Absorption

Outline of MS4SSA Lecture Modules

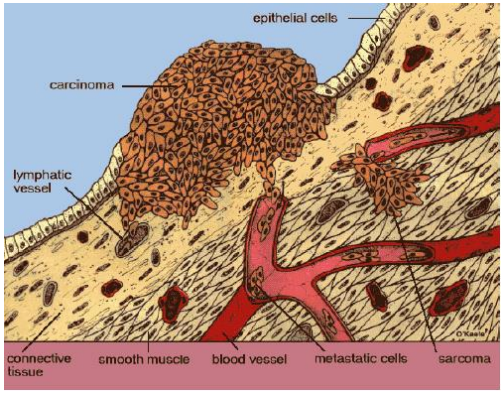
- Introduction to materials science and engineering
- Crystal structure and crystallography
- Introduction to mechanical properties
- Plasticity and deformation
- Fracture and fatigue
- Phases and phase diagrams
- Materials and their mechanical properties
- Electrical properties of materials
- Biomaterials and bio-inspired design
- Materials selection and design
- Project-based modules – renewable energy/clean water

WPI MS4SSA Materials and Project-Based Modules

- Work with the WPI Team and the African Nodes to develop modules for the teaching of materials science and engineering in African secondary schools
- The modules are presented at a level that can be taught to students in the final year of secondary school
- The modules include lecture materials, homework questions, quizzes, answer keys and project-based modules
  - Lecture materials (structure, properties, processing, materials selection and design)
  - Interdisciplinary project-based approach to solving African problems (clean water, clean energy)

Materials and Project-Based Approach

- **Advanced Materials (Bio and Nano)**
  - Targeting of disease
  - Alternative energy
- **Societal Development**
  - Affordable infrastructure e.g. recycling of agricultural & industrial waste
  - Value addition to people, minerals a natural products



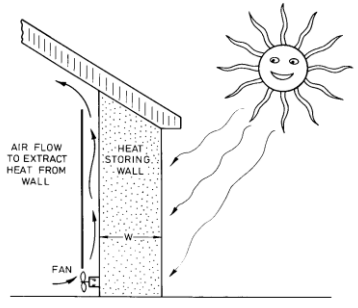
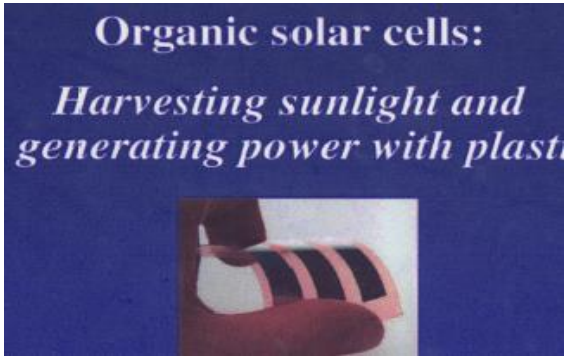
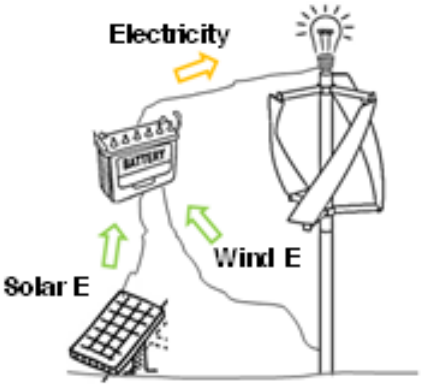


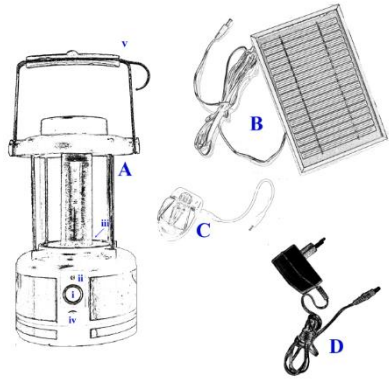
FIG. 6.32 A heat-storing wall. The sun shines on the outside during the day; heat is extracted from the inside at night. The heat diffusion time through the wall must be about 12 hours.



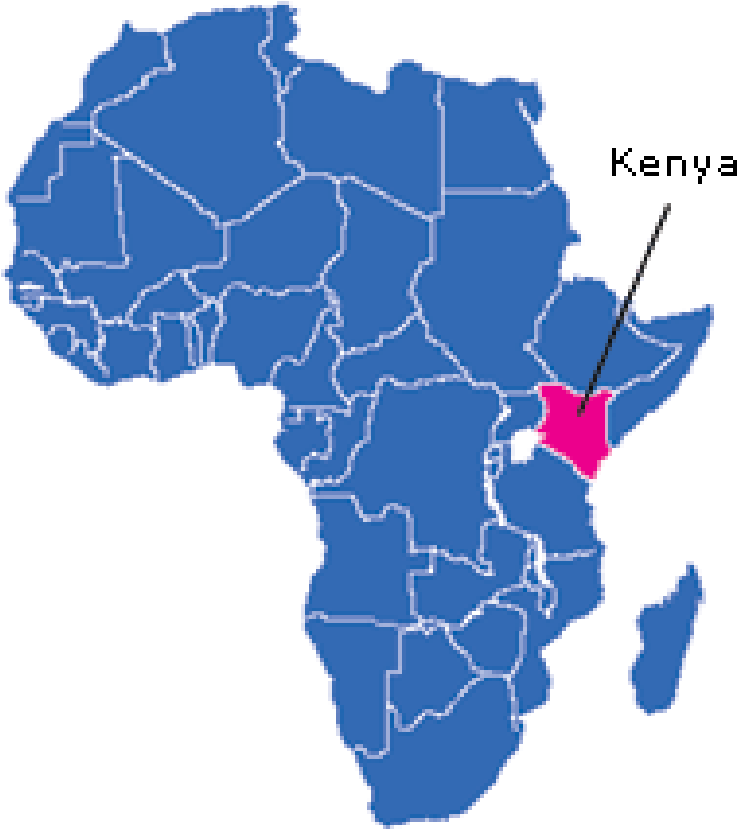
Holistic Problem Solving Project-Based Approach to Materials

- MS4SSA Materials Modules (Grades 11 & 12)
- Project-Based Modules
  - Water Purification
  - Clean Energy
- Implementation Strategy





Global Development Network



AFRICA

Project-Based Module on Clean Water

Project-Based Approach

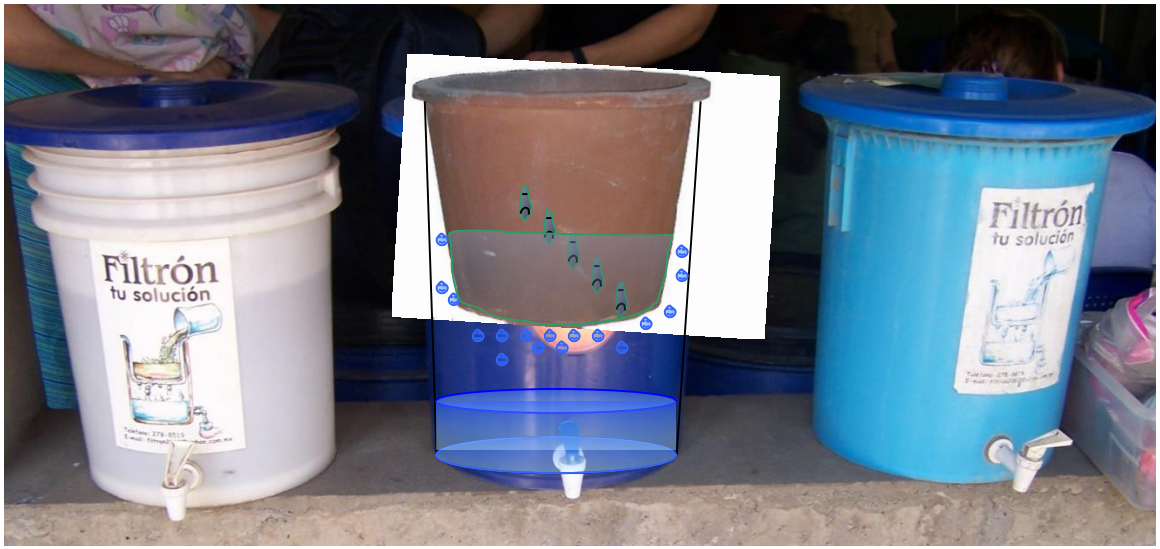
- Identify societal problem and/or developmental need
- Explore possible solutions within a scientific and engineering framework
- Develop and test potential solution
- Propose potential strategies for going from ideas to markets/policy

From Problem to Solution

Water Treatment Methods

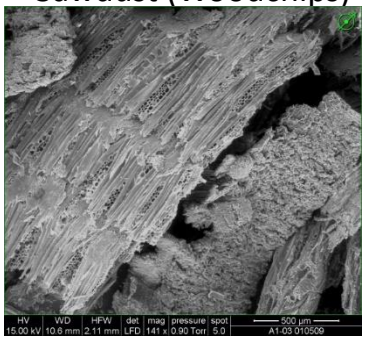
Solutions	Pros	Cons
Boiling Water	- 100% potable if boiled for at least 20 min. - Can be done in the home all year round.	- Requires time to gather fuel (fire wood) - Requires time for heating and cooling - Causes a Change in the taste of water - Method does not remove turbidity
Adding Chlorine	-Effectively kills bacteria -Simple to use -Can be used anytime -Low cost technology	-Effects the taste of water -Must be applied periodically -Does not remove turbidity -Most be purchased and transported
SODIS	-Low cost -Can be large or small -Remove turbidity -Can be us	-Does not work in shade, night or rainy season -Requires 4-6 hours to reach required to heat -Requires Time for water to cool -Change in the taste of the Water. -Does not remove turbidity
Bio Sand Filter	- Can be large or small -Easy to use -Local materials	-Appropriate sand must be available. -Does not remove microbio. contaminants -Time to cultivate bio-sand.
Filtròn Water Filter	- Kills bacteria 99% - Easy to use -One time transportation -No change of taste -Culturally acceptable - Self-encased water Container permits serving. - Made locally -Works all year around 24 hours a day. -Low cost	- Cost, US$ 7.50 to $25.00 (depending on country) - Heavy compared to the other systems. - Fragile, easy to break - Periodic cleaning is required (turbid water clogs the filtering element). - Combustion for the production process - Should be replaced after two years
PuR (P&G)	-Effective -Good for emergencies	-expensive (US $ 4.20 a month) US $0.14 cents a day for 20 liters

Point-of-Use Water Filtration Systems

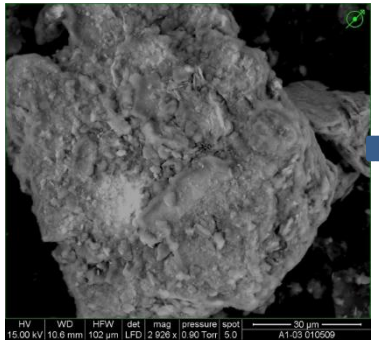


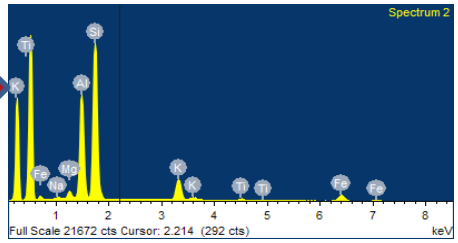
Materials Science: Surface Morphology and Chemical Composition - SEM/EDX

Sawdust (Woodchips)

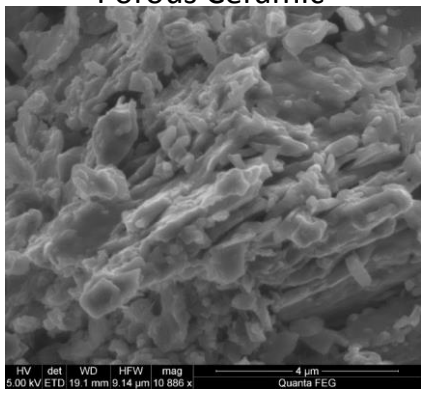


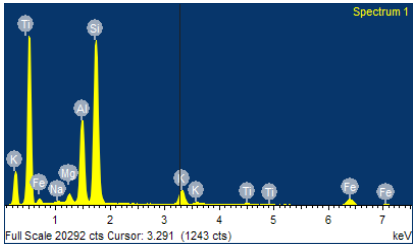
Clay (Redart)

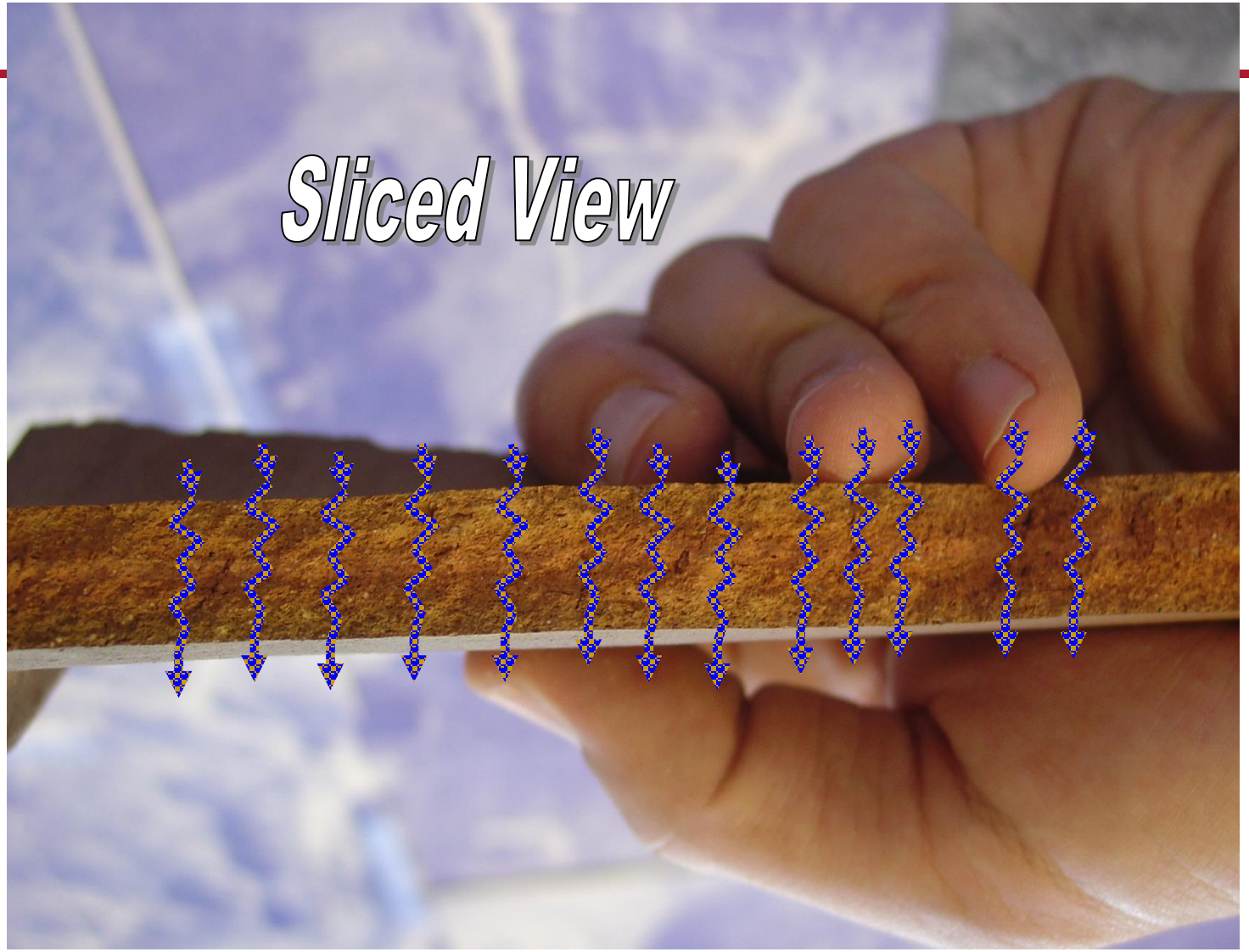




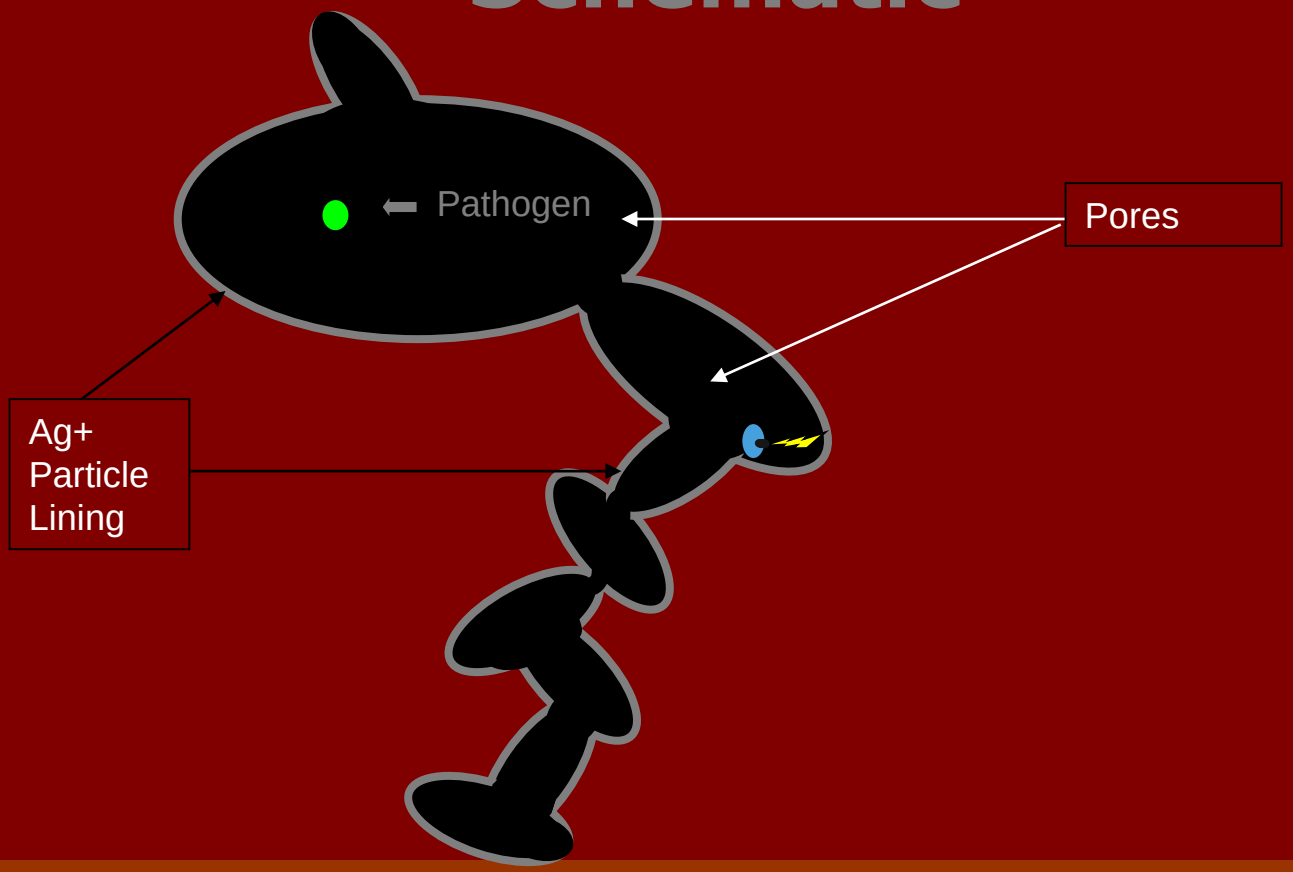
Porous Ceramic






Sliced View

Schematic



Size Comparison

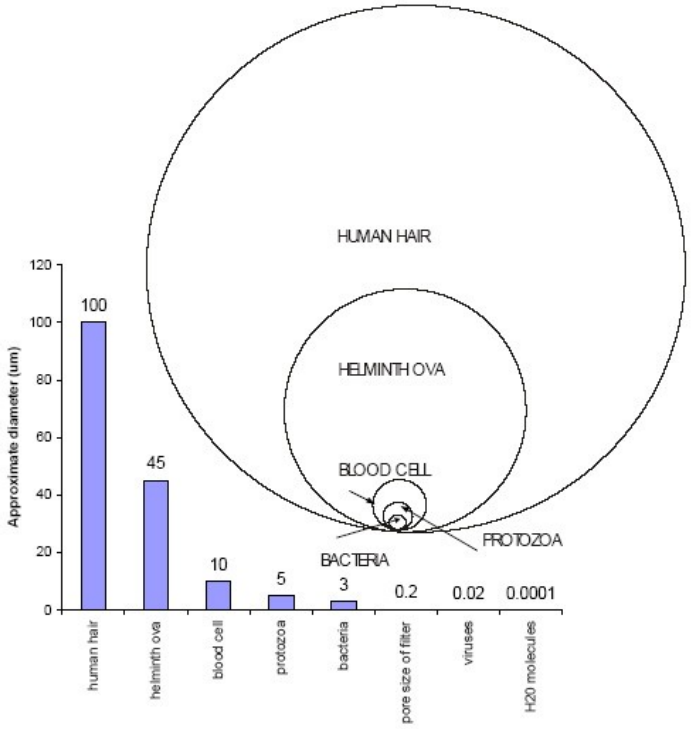


Figure 2. Comparison of relative sizes of various contaminants in water. Based on these, the pore size of the ceramic filter, at 0.2μm, would be about the size of a full stop on this page.

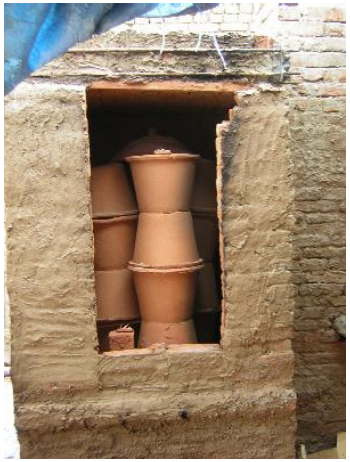
E. Coli Filtration Tests of Non-Coated Ceramic Water Filters

Volume Fraction Clay:Sawdust	Test 1	Test 2	Average ± Range
45:55	99.97	99.85	99.91 ± 0.06
50:50	99.99	99.93	99.96 ± 0.03
55:45	99.52	99.84	99.68 ± 0.16
65:35	99.99	99.99	99.99 ± 0.00

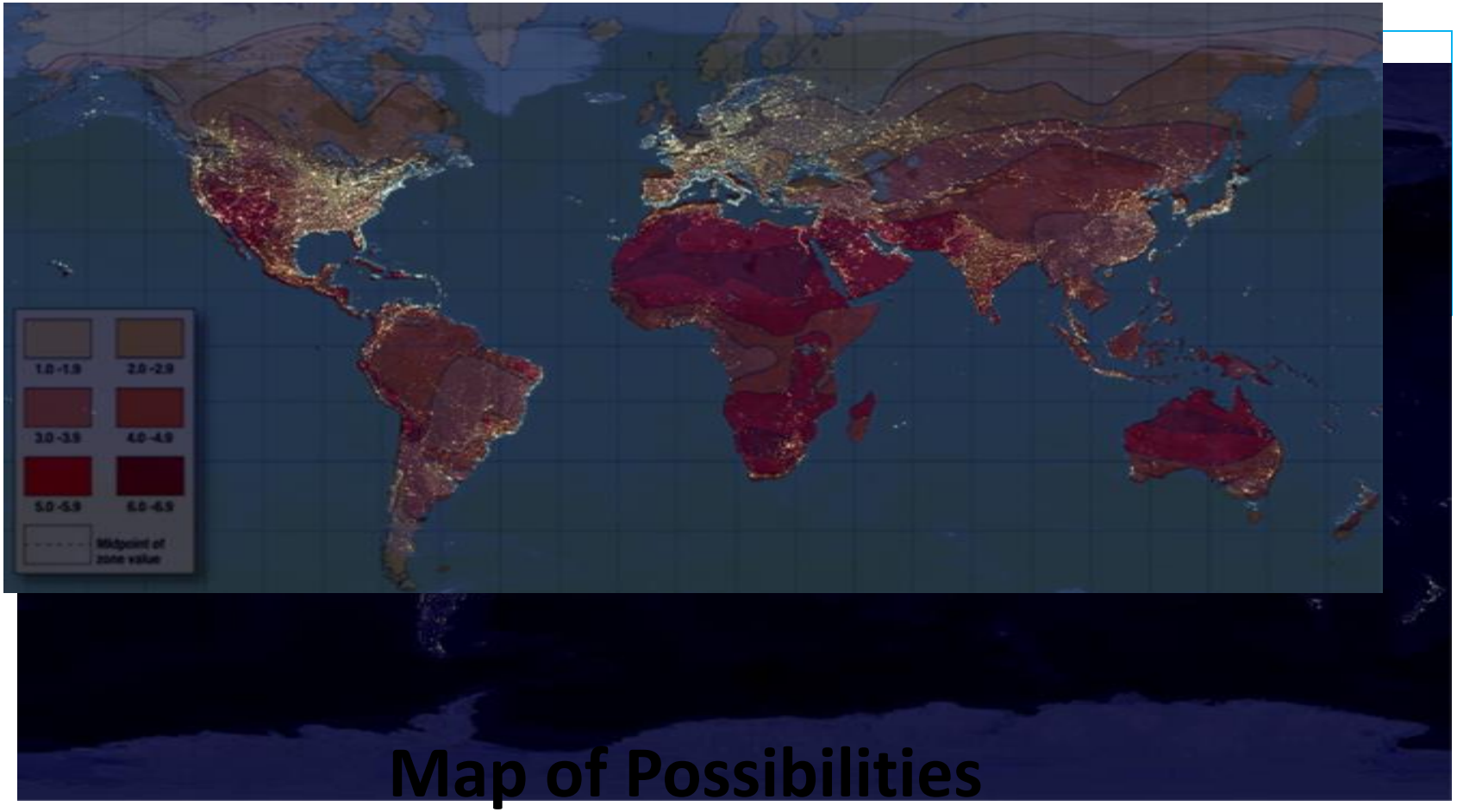
Filter Processing - From Ideas to Markets







Motivating Energy Independence of Africa: Solar Energy



Map of Possibilities

Map of the World at Night


Sustainable Energy

Project-Based Module on Clean Energy

Project-Based Approach

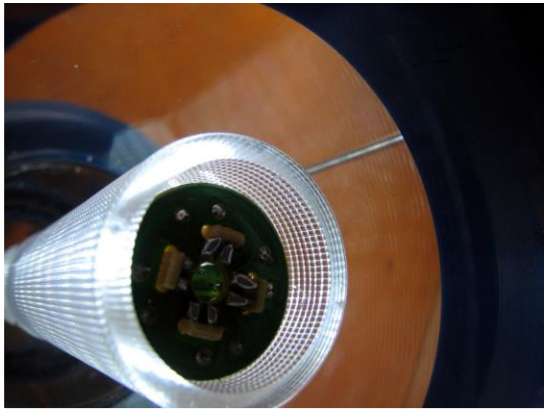
- Identify societal problem and/or developmental need
- Explore possible solutions within a scientific and engineering framework
- Develop and test potential solution
- Propose potential strategies for going from ideas to markets/policy

From Problem to Solution

Types of lighting and energy sources

Solar Lanterns:

- 28-pc LED light
- 6V Battery
- 9V Solar Panel
- 6V AC Charger
- Universal charger for mobile phone batteries



WPI

Strategy for WPI Robotics Modules

- Robotics is a way of building the interest of students in coding and engineering
- The objective of the WPI modules is to leverage our rich history of K-12 robotics outreach with hands-on competitions that stimulate the interest of high school and undergraduate students
- Approach
  - K-12 outreach (FIRST Robotics)
  - Robotics competitions (Battle Cry)
  - FIRST Global (Olympic Games of Robotics)
  - First undergraduate degree in robotics in the USA

Overview of Robotics Modules

- The approach is based on WPI's motto of theory and practice
- Active hands-on learning
- Building on emerging culture of robotics in Africa
  - Kenya
  - Ashesi University in Ghana
  - Senegal
  - Several countries participating in FIRST Global Competition
- WPI robotics modules include the following components
  - Algorithms and coding
  - Mechanical mechanisms and robot assembly
  - Vision and control

Summary & Concluding Remarks

- This talk presents an overview of curriculum development for the materials science, robotics and PBL modules that are part of the MS4SSA program
- The teaching modules present an introduction to materials science and engineering – structure, properties, processing, materials selection & design
- They enable a more intuitive approach to learning how to use the materials around us for different functions
- The teaching modules are complemented with project-based learning and robotics approaches that teach "problem solving" and engineering within an African/global context
- We welcome your engagement in using human capacity in science and engineering as engines for African development...

MS4SSA

Math and Science for
Sub-Saharan Africa

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WPI

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