WPI MS4SSA Modules: From Materials to Robotics and Project-Based Learning

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WPI Approach to Theory and Practice

• 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 and team work informed by global best practices
• African Governments
  – Gambia, Ghana, Ethiopia, Zanzibar, Lesotho, Malawi, Mauritius, Mozambique, Nigeria, Rwanda, Burkina Faso, Benin, Guinea, Senegal, Togo, Niger, Mauritania
• Participating Institutions and Collaborators
  – From Africa, Japan, India, China and the United States
Initial WPI Modules: Building a Culture of S&T in Africa

- NJCTL modules focus on math and science for primary and secondary schools
- 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)
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

Worcester Polytechnic Institute
Background and Introduction

• Africa is rich in mineral and materials resources
• However most students in Africa have never heard about materials science and engineering
• Hence most of their knowledge of math and science is abstract and not connected to the materials opportunities around them
• Furthermore the most students do not know much about how to add value to natural resources through processing
• There is therefore a need to develop materials modules that could increase the pipeline of students that can pursue future careers in 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 and natural products
Structure of the Presentation

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

- Work with the WPI Team, ASM International, Pete Gange and the World Bank Team 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)
Outline of MS4SSA Lecture Modules

• Introduction to materials science and engineering
• Crystal structure and crystallography
• Materials processing and characterization
• 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
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
# Water Treatment Methods

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

Sawdust (Woodchips)

Clay (Redart)

Porous Ceramic
Size Comparison

Figure 2. Comparison of relative sizes of various contaminants in water. Based on these, the pore size of the ceramic filter, at 0.2 μm, would be about the size of a full stop on this page.
# E. Coli Filtration Tests of Non-Coated Ceramic Water Filters

<table>
<thead>
<tr>
<th>Volume Fraction Clay:Sawdust</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Average ± Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>45:55</td>
<td>99.97</td>
<td>99.85</td>
<td>99.91 ± 0.06</td>
</tr>
<tr>
<td>50:50</td>
<td>99.99</td>
<td>99.93</td>
<td>99.96 ± 0.03</td>
</tr>
<tr>
<td>55:45</td>
<td>99.52</td>
<td>99.84</td>
<td>99.68 ± 0.16</td>
</tr>
<tr>
<td>65:35</td>
<td>99.99</td>
<td>99.99</td>
<td>99.99 ± 0.00</td>
</tr>
</tbody>
</table>
Filter Processing - From Ideas to Markets
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
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
Proposed Implementation Strategy

- African countries and regional nodes work with MS4SSA team to implement materials science and engineering, project-based learning and robotics modules

- Work with selected nodes on the training of trainers in pedagogy + use of teaching modules and project-based approach to materials science and engineering in SSA
  - 4 initial nodes in SSA (Rwanda, Nigeria, Niger and Gambia)
  - Trainers will include experts from teacher training colleges, secondary school teachers, university lecturers/professors, government officials, development partners and African networks (Materials and Robotics)

- Work with interested nodes and countries to scale and test the impact of the modules on desired outcomes

- Assess the effectiveness of the training modules at the local and regional scales

- Refine the training modules for continuous improvement
Summary & Concluding Remarks

• This talk presents an overview of 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...
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THANK YOU!

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