Framework for Teaching K12 Science and Engineering Bioenergy Concepts

A Delphi Expert Study

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Chicago, IL
What is Bioenergy?

Source: Flickr.com
Adults Don’t Know Energy

Adults Able to Name One Alternative Energy Source

Sample: 1001 adults.
(Bittle, Rochkind, & Ott, 2009)
Children Don’t Know Energy

Middle School Students Able to Identify a Biofuel in List

Sample: 3254 MS & HS Students in NY
DeWaters & Powers, 2011
Motivations

• Low bioenergy competency
  (DeWaters & Powers, 2011)

• STEM integration

• NGSS cross-cutting concept – Energy
  (National Academy, 2013)

• Energy often taught in silos
  (Chen, Scheff, Fields, Pelletier, & Faux, 2014)

• Situate Learning in socio-scientific context
  (Sadler, 2009)
Delphi Methods

• Group Problems

• Delphi Technique – Mixed method
  ▪ Experts at a distance
  ▪ Anonymous communication
  ▪ Multiple iterations
  ▪ Statistical analysis
  ▪ Develop consensus

Participants

• **Criteria:** PhD in bioenergy, published in the field, or taught bioenergy courses

• **Background**
  - Ecology
  - Sustainability
  - Environmental engineering
  - Transportation engineering
  - Biology
  - Spatial Technologies
  - Horticultural
• Question: What science and engineering concepts are essential in K12?

• Round 1 – Brainstorming (Qualitative)

• Round 2 – Narrowing Down (Quantitative)

• Round 3 – Rating (Quantitative)
## Round 2: Science Results

<table>
<thead>
<tr>
<th>Concept</th>
<th>Rating</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Climate Change:</strong> Historical record and projected consequences</td>
<td>4.6</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Energy Fundamentals:</strong> Work, energy, conversions</td>
<td>4.5</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Photosynthesis:</strong> How light energy is stored in plants</td>
<td>4.4</td>
<td>0.9</td>
</tr>
<tr>
<td><strong>Chemical Cycles:</strong> Water, carbon, nitrogen cycles</td>
<td>4.3</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Ecosystems:</strong> Ecology and human impact</td>
<td>4.2</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Conversion Principles:</strong> Types of conversions</td>
<td>4.2</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>Lifecycle Assessment:</strong> Environmental impacts from cradle to grave</td>
<td>4.2</td>
<td>0.9</td>
</tr>
<tr>
<td><strong>Economics:</strong> How economics impacts biofuel use</td>
<td>3.9</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>Biomass Sources:</strong> How solar energy is stored</td>
<td>3.8</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>Laws of Thermodynamics:</strong> Conservation of energy</td>
<td>3.8</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Public Policy:</strong> Impacts of politics on bioenergy production</td>
<td>3.3</td>
<td>1.4</td>
</tr>
</tbody>
</table>
## Round 2: Engineering Results

<table>
<thead>
<tr>
<th>Concept</th>
<th>Rating</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Consumption: Current and historical energy sources</td>
<td>4.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Energy Fundamentals: Types and conversions of energy</td>
<td>4.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Energy Requirements: Quantity and type of energy needed</td>
<td>4.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Nature of Engineering: Role of engineering in bioenergy</td>
<td>4.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Conversion Technologies: Types of conversions</td>
<td>3.9</td>
<td>1.2</td>
</tr>
<tr>
<td>Bioenergy Products: Types of biofuels</td>
<td>3.7</td>
<td>1.1</td>
</tr>
<tr>
<td>Lifecycle Assessment: Social, environmental, and economic impacts</td>
<td>3.7</td>
<td>1.1</td>
</tr>
<tr>
<td>Process Economics: Economic analysis of conversion processes</td>
<td>3.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Chemical Engineering Fundamentals: Conservation mass/energy; heat/mass transfer</td>
<td>3.3</td>
<td>1.5</td>
</tr>
</tbody>
</table>
# Round 3: Findings

<table>
<thead>
<tr>
<th>Concept</th>
<th>Rating</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td><strong>Energy Requirements:</strong> Quantity and type of energy needed</td>
<td>4.88</td>
<td>.35</td>
</tr>
<tr>
<td><strong>Energy Consumption:</strong> Current and historical energy sources</td>
<td>4.88</td>
<td>.35</td>
</tr>
<tr>
<td><strong>Climate Change:</strong> Historical record and consequences</td>
<td>4.88</td>
<td>.52</td>
</tr>
<tr>
<td><strong>Nature of Engineering:</strong> Role of engineering in bioenergy</td>
<td>4.62</td>
<td>.52</td>
</tr>
<tr>
<td><strong>Energy Fundamentals:</strong> Work, energy, conversions</td>
<td>4.63</td>
<td>.52</td>
</tr>
<tr>
<td><strong>Lifecycle Assessment:</strong> Environmental impacts cradle to grave</td>
<td>4.50</td>
<td>.52</td>
</tr>
<tr>
<td><strong>Photosynthesis:</strong> How light energy is stored in plants</td>
<td>4.38</td>
<td>.46</td>
</tr>
<tr>
<td><strong>Conversion Principles:</strong> Types of conversions</td>
<td>4.38</td>
<td>.52</td>
</tr>
<tr>
<td><strong>Chemical Cycles:</strong> Water, carbon, nitrogen cycles</td>
<td>4.25</td>
<td>.35</td>
</tr>
<tr>
<td><strong>Ecosystems:</strong> Ecology and human impact</td>
<td>4.25</td>
<td>.52</td>
</tr>
</tbody>
</table>
Bioenergy Framework & NGSS

• **Climate Change**
  MS-ESS3.D: Global Climate Change
  Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth’s mean surface temperature (global warming).

• **Energy Fundamentals**
  HS-PS3.A: Definitions of Energy
  PS3.B: Conservation of Energy and Energy Transfer
“What is added in this cross cutting discussion is recognition that an understanding of these core (Energy and matter flow) ideas can be informative in examining systems in life science, earth and space science, and engineering contexts.”

(NGSS Framework, 2011, p 96)
Limitations

• Small number of participants (Linstone & Turoff, 2011)
• Experts primarily research-based bioenergy, few educators
• Mixed methods challenges
• Additional development needed for classroom practice
Implications & Next Steps

• Engineering concepts are highly rated
• Basic energy knowledge emphasized
• Emphasis on core science concepts
• Results are compatible with NGSS
• Expands on NGSS Energy and Matter
• Guide development of additional curriculum
References

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Paper available at:

ResearchGate.com/profile/Brian_Hartman
References


