Remote Online Labs: A New Model for Teaching and Learning Scientific Practices

Kemi Jona, Ph.D.

Research Professor of Learning Sciences and Computer Science at Northwestern University and Director of the Office of STEM Education Partnerships
Dr. Kemi Jona leads research and development projects in STEM curriculum design, cyber learning, online and blended learning models, and new game-based approaches to engaging youth in STEM.

The author of numerous book chapters, articles, and conference papers on the topics of online learning, curriculum design, remote labs, and learning technology and strategy, he holds a Ph.D. in Computer Science from Northwestern University and a BS with Honors in Computer Science and Psychology from the University of Wisconsin-Madison.
This product was funded by a grant awarded by the U.S. Department of Labor’s Employment and Training Administration. The product was created by the grantee and does not necessarily reflect the official position of the U.S. Department of Labor. The Department of Labor makes no guarantees, warranties, or assurances of any kind, express or implied, with respect to such information, including any information on linked sites and including, but not limited to, accuracy of the information or its completeness, timeliness, usefulness, adequacy, continued availability or ownership.
Remote Online Labs: A New Model for Teaching and Learning Scientific Practices

Kemi Jona, Ph.D

NANSLO / WICHE Webinar 9/16/13
• Professor of Learning Sciences and Computer Science at Northwestern University
• Director of Office of STEM Education Partnerships
• Research focus: advanced learning technologies for STEM education, online & blended learning
• Former Director of Academic Programs at Carnegie Mellon-Silicon Valley
• Independent consultant to businesses, higher ed, and K-12 schools on online & blended learning, learning technologies
Scientific Practices

• Asking questions (for science) and defining problems (for engineering)
• Developing and using models
• Planning and carrying out investigations
• Analyzing and interpreting data
• Using mathematics and computational thinking
• Constructing explanations (for science) and designing solutions (for engineering)
• Engaging in argument from evidence
• Obtaining, evaluating, and communicating information
WHAT ARE REMOTE LABS?
Experiment Design

- **Distances (mm):** 30, 50
- **Measurement Time (s):** 1, 10
- **Number of Trials:** 1, 10

Current experiment run time based on these settings:
2 secs (10 mins max)

Lab Saved: 01/16/2011 10:45:11 AM
Northwestern X-ray powder diffraction iLab

- Identification of unknown crystalline materials
- Measurement of sample purity
X-ray powder diffractogram

Image courtesy the USGS.
MIT Microelectronics Device Characterization iLab
MIT Force on a Dipole iLab

LabVIEW 8.2 Lab Server

Run Experiment

FORCE ON A DIPOLE

Top coil
Damp Magnet
Power

Frequency
Amplitude
Data Description
Record

Signal Generator

Field Visualization

Experiment setup and visualization of magnetic forces on a dipole.
MIT Neutron Beam iLab
ARE REMOTE LABS SCALABLE?
Device located in Queensland Australia!
Organic User Growth

Cumulative User Registrations

User Registrations

Month-Year

0 0

0 2000

0 4000

0 6000

0 8000

Scalable Delivery of Experiments (~11,000)
When is the lab used?

**Student Experiments Run By Hour (CST)**
University of Technology Sydney
Remote Lab Facility
ARE REMOTE LABS EFFECTIVE?
## Pre/Post Learning Gains

N=594 students

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall Learning Gain</strong></td>
<td>15%</td>
</tr>
<tr>
<td>(% score increase, 18 items)</td>
<td></td>
</tr>
<tr>
<td><strong>Statistical significance</strong></td>
<td>P ≤ 0.0001</td>
</tr>
<tr>
<td><strong>Effect size</strong></td>
<td>0.80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>21%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Content Learning</strong></td>
<td></td>
</tr>
<tr>
<td>Statistical significance</td>
<td>P ≤ 0.0001</td>
</tr>
<tr>
<td><strong>Effect size</strong></td>
<td>1.03</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>8%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Process Learning</strong></td>
<td></td>
</tr>
<tr>
<td>Statistical significance</td>
<td>P ≤ 0.0001</td>
</tr>
<tr>
<td><strong>Effect size</strong></td>
<td>0.37</td>
</tr>
</tbody>
</table>

Better retention

Content Learning

At the one week follow up – Remote users remembered more (F = 3.113, p = .065)

Source: Michael Downing (2012), Undergraduate Thesis, Northwestern University Dept. of Psychology
For students conducting more than one run of the experiment

N=352

<table>
<thead>
<tr>
<th>Experiment Design Parameter</th>
<th>First Run</th>
<th>Second Run</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of distances</td>
<td>5.8</td>
<td>7.7</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Average measurement time</td>
<td>5.5</td>
<td>5.8</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Average number of trials</td>
<td>5.0</td>
<td>5.5</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Research question quality</td>
<td>1.47</td>
<td>1.54</td>
<td>p &lt; 0.05</td>
</tr>
</tbody>
</table>

Flexibility of access = greater opportunity to engage in scientific inquiry

<table>
<thead>
<tr>
<th>First Run of Experiment</th>
<th>N</th>
<th>Distances</th>
<th>Measurement Time</th>
<th>Trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Class</td>
<td>238</td>
<td>5.04</td>
<td>5.10</td>
<td>4.50</td>
</tr>
<tr>
<td>Out of Class</td>
<td>342</td>
<td>7.21</td>
<td>6.17</td>
<td>6.31</td>
</tr>
</tbody>
</table>

✓ Experimental designs were of higher quality when used out of class time

Flexibility of access = greater opportunity to engage in scientific inquiry

<table>
<thead>
<tr>
<th>In class</th>
<th>Out of Class</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students conducting 3 or more experimental runs</td>
<td>4.6%</td>
<td>12%</td>
</tr>
</tbody>
</table>

✓ When used out of class time, 3X students voluntarily did more experiments than required

HOW DO REMOTE LABS COMPARE WITH SIMULATIONS?
Remote Lab vs. Simulation

• **Students who did a remote lab were more likely to feel as though they did a real experiment** \((f = 8.24, p < .01)\). Students liked that the remote lab used real instruments that they actually could control.

• **Very few students who did the remote lab would want to do the simulation instead.** The majority in both labs would prefer the remote lab, but there is a main effect of condition \((\chi^2 = 8.074, p < .05)\).

• **Those who did a remote lab would not want to run a simulation multiple times, but those who ran a simulation would want to run a remote lab multiple times** \((\chi^2 = 18.58, p < 0.001)\). Students were more likely to attribute experience of an experiment (re-running trials) to the remote lab.

Remote Lab vs. Simulation

• **Key results**
  – Participants who used the remote lab wrote higher-quality research questions [$F(1, 121) = 15.99, p < .01$]
  – Remote lab users who saw a video of the device wrote higher-quality questions than did users who saw only a photo [$F(1, 60) = 12.04, p < .01$], but simulation users did not show this difference [$F(1, 59) = .258, p = N.S.$]

• **Implications**
  – Remote lab users seemed more invested in the actual experiment—they crafted better research questions, considered how their experiment limited human error while also evaluating other possible sources of variability in their data, and wanted to run their experiment multiple times
  – Remote users who watched the video felt most engaged with the task

Challenges

1. Teacher preparation & tools
2. Age-appropriate interfaces & materials (esp. K-12)
3. Greater availability
4. Policy barriers (e.g., UCOP)

Exposure to cyber-enabled tools is essential in preparing today’s students to be the scientists and engineers who will drive the next generation of discovery and innovation...
Future Work

- Easier access & sharing via standardized interfaces
- Better tools for instructors
- Personalization of the laboratory learning experiences with learning analytics/assessments
- Mobile interfaces
- Supporting laboratory science MOOCs
Summary of Findings

- Remote labs support effective learning
- Remote labs have unique affordances not shared by other online tools:
  - By creating an authentic online experience grounded in reality, remote labs helped students to engage in scientific inquiry when the necessary lab equipment was not locally available
  - Participating in real research leads students to gain confidence and “feel like a scientist” (Hunter, Lausen, & Seymour, 2006)
- Because remote online labs feel authentic and are easy for students to access, their implementation could have a positive effect on student experiences and outcomes for STEM education
Remote labs benefits

- Remote labs are scalable (though more work ahead)
- Remote labs allows the laboratory interaction to be tailored specifically to learning goals and audience
- Remote labs, when implemented appropriately, can provide a more personalized learning experience for all students
  - Better & more access
  - Better feedback
  - Individual pacing
Thank you!

kjona@northwestern.edu

**Acknowledgements:** This work is supported in part by the National Science Foundation under grants IIS-1216389, OCI-0753324, and DUE-0938075, and DMR-1121262 (to the Materials Research Center of Northwestern University), and by a grant from Hewlett-Packard under the HP Catalyst Initiative. However, any opinions, findings, conclusions, and/or recommendations are those of the investigators and do not necessarily reflect the views of the funders. We thank the University of Queensland for providing access to their remote labs.