Evaluating a Scientific Collaboratory: Results from a Controlled Experiments

Diane H. Sonnenwald

Göteborg University & University College of Borås
Collaboratory Team

*Information Science:* Diane Sonnenwald, Kelly Maglaughlin, Bin Li

*Computer Science:* Mary Whitton, Russ Taylor, Kevin Jeffay, Don Smith

*Physics:* Rich Superfine, Martin Guthold

*Chemistry:* Dorothy Erie, Tom Kunkel, Sam Wilson

*Gene Therapy:* Douglas McCarty, Jude Samulski

*Student Research Assistants:* 5 distributed across IS, CS, Physics
Research Motivation

National Institutes of Health (NIH) Policy Issue

To provide access to specialized scientific instruments, should NIH:

(1) continue funding scientists’ travel
    - or -
(2) fund the development of collaboratories

What impact might collaboratories have on the scientific process & outcomes?
Research context: nanoManipulator (nM)

Enables scientists to interact directly with physical samples, ranging in size from DNA to cells

(Taylor & Superfine, 1999; Guthold, et al., 1999)
Single-user nanoManipulator

Display Control Software

3D Display of Sample

Atomic Force Microscope (AFM) Controls & Analysis Tools

Data Analysis Software

Haptic Feedback Device

Video Display from AFM Camera
Research Approach

- Ethnographic Field Study
- System Design & Development
- Experimental Evaluation
Collaborative nM System

- Shared app’s for AFM control & data analysis tools
- Haptic Feedback Device
- Cameras
- 3D Display of Sample & Display Control Software
- Writing tablet
- Audio (phone)
Collaborative nM

Connect to machine: tungsten-

View private state

Copy

View shared state

measure
Issues in Evaluation

• Need to integrate:
  - Purpose of evaluation
  - Context of scientific use and typical tasks
  - Resources available

• Additional challenges for collaboratories
  - Geographic distribution of participants
  - Rhythm of science
  - Number of participants willing & needing to use new, specialized system
Experimental Evaluation

Repeated Measures Design

**FtF – Remote Collaboration**

**Realistic scientific tasks**

**Multiple Measures**

Scientific task performance, Participants’ perceptions & attitudes regarding innovation adoption

Remote < FtF
Study Participants

- 40 upper-level undergraduate science students working in pairs
- 19 males, 21 females
- Majors: 23 biology, 6 physics, 5 chemistry, 4 biochemistry, 1 biomaterial science, 1 biomedical materials
- 36 Caucasian, 2 African-American, 2 Indian
- Self-reported GPA

<table>
<thead>
<tr>
<th>Grade</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+/A</td>
<td>10</td>
</tr>
<tr>
<td>A-/B+</td>
<td>15</td>
</tr>
<tr>
<td>B/B-</td>
<td>13</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
</tr>
</tbody>
</table>
Experiment Format

(1) Intro to experiment, instrument & science

(2) Two lab sessions or “Research Experiences”
   - Hands-on self-guided tutorial, assistance available
   - Scientific research tasks using system
   - Participants asked to create lab report (collect data & answer questions)
   - up to 5 hours in length

<table>
<thead>
<tr>
<th></th>
<th>Lab -1</th>
<th>Lab -2</th>
</tr>
</thead>
<tbody>
<tr>
<td>FtF</td>
<td>Pairs 1-10</td>
<td>Pairs 11-20</td>
</tr>
<tr>
<td>Remote</td>
<td>Pairs 11-20</td>
<td>Pairs 1-10</td>
</tr>
</tbody>
</table>
Remote Setting
Face-to-face Setting
## Face Validity

<table>
<thead>
<tr>
<th>Post-survey responses</th>
<th>AVG</th>
<th>FtF</th>
<th>Remote</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe this lab is similar to work scientists do</td>
<td>3.66</td>
<td>3.77</td>
<td>3.55</td>
</tr>
<tr>
<td>Concentrated fully on activity</td>
<td>4.31</td>
<td>4.25</td>
<td>4.36</td>
</tr>
<tr>
<td>Time given to perform tasks</td>
<td>4.41</td>
<td>4.52</td>
<td>4.30</td>
</tr>
<tr>
<td>I was provided ample training</td>
<td>4.50</td>
<td>4.45</td>
<td>4.55</td>
</tr>
</tbody>
</table>

“Everything was like for real”

“I thought it was not too long, not too short… didn’t make me feel unsure of what I was doing.”
### Data Collection

#### Introduction session

**Surveys:**
- Demographic data
- Technical skills
- Learning & work styles

#### Each “Research experience”

- Group lab report: Scientific task performance
- Video tape:
  - Overhead view
  - Side-angle view
  - Both monitors
- Audio-tape
- Observer notes
- Post-survey: Innovation adoption
- Post-interview: Participants’ perceptions
Innovation Adoption: Post-questionnaire

Rogers’ Attributes of Innovation Adoption (1995)

- Relative advantage
- Compatibility
- Trialability
- Observability
- Complexity

- Validated & used in a variety of domains, including information systems (e.g., Moore & Benbasat, 1991)
- Theoretical framework helps to insure instrument validity (Anatasi, 1986)
Post-Questionnaire Data Analysis

- Averages for each 5-point scale: 3.42 to 4.33
- Multivariate analysis of variance (MANOVA)
- No significant statistical difference between FtF and remote conditions for any scale
- Relative advantage significantly higher after second research experience ($p < .01$)
- Two alternative conclusions:
  - A poorly constructed instrument
  - Equally effective system for given task

Data triangulation
Performance Measure: Group Lab Reports

- Based on scientist’s lab work
- Data images, data values, graphs, annotations, explanations
- Blind grading by three instructors
- Intercoder reliability
Performance Measure: Group Lab Reports

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean Lab Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>FtF</td>
<td>Collaborated FtF 1st</td>
</tr>
<tr>
<td></td>
<td>.70 (lab1)</td>
</tr>
<tr>
<td>Remote</td>
<td>.75 (lab2)</td>
</tr>
</tbody>
</table>

- MANOVA analysis of differences between scores
- No significant difference between FtF & Remote (df=1, F=2.670, p=.12)
- Collaborating remotely first yielded higher subsequent performance (df=1, F=9.66, p=.006)
Participants’ Perceptions: Interviews

- Conducted 1-1 with each study participant after each experiment session
- 80 interviews
- Interview questions
  - Satisfying & dissatisfying aspects (Flanagan, 1954)
  - Specific incidents noted by observer
  - Work patterns
  - Technology impact on their interaction
  - Comparisons between working FtF and remotely
Interview Analysis

Comparing Remote to FtF

<table>
<thead>
<tr>
<th>Disadvantage</th>
<th>Advantage/Coping Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction less personal</td>
<td>But doesn’t matter for this work</td>
</tr>
<tr>
<td>Fewer cues from partner</td>
<td>Talk more frequently &amp; descriptively</td>
</tr>
<tr>
<td>Harder to interrupt partner</td>
<td>Easier to explore system &amp; ideas independently</td>
</tr>
<tr>
<td>Harder to see everything</td>
<td>Having exact same view of data visualization is better</td>
</tr>
<tr>
<td>Turn-taking in NetMeeting</td>
<td>Can work simultaneously on data visualization</td>
</tr>
</tbody>
</table>
Limitations

- Students vs. postdocs & faculty as participants
- Repeated measures design vs. Solomon four-group design
- Equivalency of lab sessions assumed
- Not all scientific tasks included, e.g., experiment design
- Sample size
Discussion

• Results illustrate remote collaboration:
  - is acceptable to users
  - yields acceptable outcomes
• Hypotheses that remote < FtF not supported
• No statistically significant differences between FtF & remote lab grades
  - Participants who worked remote first, performed better in subsequent session
• Interview data provides information about advantages & coping strategies
• No statistically significant differences in attitudes towards innovation adoption between FtF & remote
Possible Theoretical Explanation

Structures of the Life World (Schutz & Luckman, 1985)

- Problematic situation
  Can’t assume the physical world is the same for both of us

- Motivation to develop a shared reality (intersubjectivity)

- Individuals assume:
  (1) differences will not keep us from achieving our goals (congruence of relevance systems)
  (2) if you were with me, you would experience things the same way (interchangability of standpoints)
Acknowledgement

The development of the nanoManipulator has been funded by the NIH National Center for Research Resources, NCRR 5-P41-RR02170.

For more information see:

