TEACHING CHEMISTRY AND OTHER SCIENCES TO 
BLIND AND LOW-VISION STUDENTS THROUGH HANDS-ON LEARNING 
EXPERIENCES IN HIGH SCHOOL SCIENCE LABORATORIES

A Dissertation in 
Chemistry

by

Cary Alan Supalo

© 2010 Cary Alan Supalo

Submitted in Partial Fulfillment 
of the Requirements 
for the Degree of

Doctor of Philosophy

December 2010
The dissertation of Cary Alan Supalo was reviewed and approved* by the following:

Thomas Mallouk
DuPont Professor of Materials Chemistry and Physics
Dissertation Adviser
Chair of Committee

Karl T. Mueller
Professor of Chemistry

Mark Maroncelli
Professor of Chemistry

William Carlsen
Professor of Education
Department of Curriculum and Instruction

George Bodner
Distinguished Professor of Engineering, Purdue University
Distinguished Professor of Chemistry and Education, Purdue University
Special Member

Barbara J. Garrison
Shapiro Professor of Chemistry
Head of the Department of Chemistry

* Signatures are on file in the Graduate School.
ABSTRACT

Students with blindness and low vision (BLV) have traditionally been underrepresented in the sciences as a result of technological and attitudinal barriers to equal access in science laboratory classrooms. The Independent Laboratory Access for the Blind (ILAB) project developed and evaluated a suite of talking and audible hardware/software tools to empower students with BLV to have multisensory, hands-on laboratory learning experiences.

This dissertation focuses on the first year of ILAB tool testing in mainstream science laboratory classrooms, and comprises a detailed multi-case study of four students with BLV who were enrolled in high school science classes during 2007-08 alongside sighted students. Participants attended different schools; curricula included chemistry, AP chemistry, and AP physics.

The ILAB tools were designed to provide multisensory means for students with BLV to make observations and collect data during standard laboratory lessons on an equivalent basis with their sighted peers. Various qualitative and quantitative data collection instruments were used to determine whether the hands-on experiences facilitated by the ILAB tools had led to increased involvement in laboratory-goal-directed actions, greater peer acceptance in the students’ lab groups, improved attitudes toward science, and increased interest in science.

Premier among the ILAB tools was the JAWS/Logger Pro software interface, which made audible all information gathered through standard Vernier laboratory probes and visually displayed through Logger Pro. ILAB tools also included a talking balance, a
submersible audible light sensor, a scientific talking stopwatch, and a variety of other high-tech and low-tech devices and techniques.

While results were mixed, all four participating BLV students seemed to have experienced at least some benefit, with the effect being stronger for some than for others. Not all of the data collection instruments were found to reveal improvements for all of the participating students, but each of the types of data sets provided evidence of benefit for varying subgroups of participants. It is the expectation of the ILAB team that continuing to implement adaptive/assistive technologies for BLV students in science laboratory classrooms will foster enhanced opportunities in science classes and professions.
TABLE OF CONTENTS

LIST OF FIGURES ...................................................................................................... x
LIST OF TABLES ........................................................................................................ xii
ABBREVIATIONS ..................................................................................................... xv
ACKNOWLEDGEMENTS ......................................................................................... xvii

Chapter 1  Introduction to the Problem ................................................................. 1
  Background ....................................................................................................... 2
  Introduction to ILAB ........................................................................................ 5
  Inclusion in Scientific Communities of Practice ............................................. 11
  Overcoming the Barriers .................................................................................. 12
  Potential Benefits of ILAB .............................................................................. 14

Chapter 2  Review of the Literature on Teaching Science to Blind and
  Low-Vision Students ....................................................................................... 15
  Teaching the Sciences to BLV Students .......................................................... 16
    Teaching Chemistry to BLV Students .......................................................... 32
    Teaching Biology to BLV Students ............................................................. 51
    Teaching Physics to BLV Students .............................................................. 57
  Summary .......................................................................................................... 64

Chapter 3  Factors in Fostering Students’ Interest in STEM Education:
  Hands-On Science, Acceptance, Achievement ............................................. 66
  Hands-On Approaches to Learning ................................................................. 67
    Summarizing the Hands-On Literature ....................................................... 84
  Student Learning: Group Dynamics and Peer Acceptance/Rejection .......... 84
    Summarizing the Peer Acceptance/Rejection Literature ...................... 97
  Tying the Factors Together .............................................................................. 97

Chapter 4  Methodology ........................................................................................ 99
  What Is Qualitative Research? ......................................................................... 99
  What Is a Case Study? .................................................................................... 102
  Design of Experiment ..................................................................................... 103
    Internal Controls .......................................................................................... 104
    Participant Selection ................................................................................... 105
  Data Collection Instruments ........................................................................... 106
    Pre- and Post-School-Year Interviews ...................................................... 106
    Scientific Attitude Inventory II (SAI II) ..................................................... 111
    Audiovisual Recordings .............................................................................. 114
## Lesson 5 Analysis: Which Is Your Metal? (I-Video)

- Graphic Analysis of Video Data ................................................................. 184
- Video Analysis Rubric Results ................................................................. 186
- Summary ...................................................................................................... 189

### Chapter 7 Highland Hills High School Case Study

- Demographics of School ............................................................................. 191
- Background of Student ................................................................................ 191
- Background of Teacher ................................................................................ 192
- Classroom Resources .................................................................................. 193
- Relationship between Investigator, Teacher, BLV Student, and Parents .... 193
- Interview Data ............................................................................................... 194
  - Excerpts, Summaries, Commentary: Pre-School-Year Student Interview   195
  - Excerpts, Summaries, Commentary: Post-School-Year Student Interview 195
  - Excerpts, Summaries, Commentary: Post-School-Year Teacher Interview 197
- SAI II Survey Data Pre/Post School Year .................................................. 198
- Overview of the Five Laboratory Lessons .................................................. 201
  - Lesson 1 Synopsis: Balance (N-Video) ..................................................... 201
  - Lesson 2 Synopsis: Speaker (N-Video) ..................................................... 202
  - Lesson 3 Synopsis: Bull’s-Eye (I-Video) ................................................... 203
  - Lesson 4 Synopsis: Falling Mass Cars (I-Video) ..................................... 203
  - Lesson 5 Synopsis: Pendulum (I-Video) .................................................. 204
- Video Task Analysis for Each Lesson ......................................................... 205
  - Lesson 1 Analysis: Balance (N-Video) ..................................................... 206
  - Lesson 2 Analysis: Speaker (N-Video) ..................................................... 208
  - Lesson 3 Analysis: Bull’s-Eye (I-Video) ................................................... 213
  - Lesson 4 Analysis: Falling Mass Cars (I-Video) ..................................... 216
  - Lesson 5 Analysis: Pendulum (I-Video) .................................................. 221
- Graphic Analysis of Video Data ................................................................. 225
- Video Analysis Rubric Results ................................................................... 227
- Summary ...................................................................................................... 230

### Chapter 8 Rollinsville High School Case Study

- Demographics of School ............................................................................. 232
- Background of Student ................................................................................ 232
- Background of Teacher ................................................................................ 233
- Classroom Resources .................................................................................. 234
- Relationship between Investigator, Teacher, BLV Student, and Parents .... 235
- Interview Data ............................................................................................... 236
  - Excerpts, Summaries, Commentary: Pre-School-Year Student Interview 236
Excerpts, Summaries, Commentary: Post-School-Year
Student Interview ................................................................. 236
Excerpts, Summaries, Commentary: Post-School-Year
Teacher Interview ................................................................. 238
SAI II Survey Data Pre/Post School Year .............................. 240
Overview of the Five Laboratory Lessons ............................. 243
Lesson 1 Synopsis: Alum Analysis (N-Video) ......................... 243
Lesson 2 Synopsis: Heat of Magnesium (N-Video) .................. 244
Lesson 3 Synopsis: Colligative Properties (I-Video) .............. 245
Lesson 4 Synopsis: Equilibrium (I-Video) ............................ 246
Lesson 5 Synopsis: Titration (I-Video) ................................. 247
Video Task Analysis for Each Lesson .................................. 248
Lesson 1 Analysis: Alum Analysis (N-Video) ......................... 249
Lesson 2 Analysis: Heat of Magnesium (N-Video) ............... 251
Lesson 3 Analysis: Colligative Properties (I-Video) .............. 254
Lesson 4 Analysis: Equilibrium (I-Video) ............................ 257
Lesson 5 Analysis: Titration (I-Video) ................................. 260
Graphic Analysis of Video Data ............................................. 265
Video Analysis Rubric Results ............................................. 267
Summary .................................................................................. 270

Chapter 9 Twin Pines High School Case Study ........................ 272
Demographics of School ....................................................... 272
Background of Student ........................................................... 272
Background of Teacher ............................................................ 274
Classroom Resources ............................................................... 274
Relationship between Investigator, Teacher, BLV Student, and Parents .......... 275
Interview Data ........................................................................ 277
Excerpts, Summaries, Commentary: Pre-School-Year
Student Interview ................................................................. 277
Excerpts, Summaries, Commentary: Post-School-Year
Student Interview ................................................................. 278
Excerpts, Summaries, Commentary: Post-School-Year
Teacher Interview ................................................................. 279
SAI II Survey Data Pre/Post School Year .............................. 281
Overview of the Five Laboratory Lessons ............................. 283
Lesson 1 Synopsis: Flame Test (N-Video) .............................. 283
Lesson 2 Synopsis: Solubility and Precipitation (N-Video) ...... 284
Lesson 3 Synopsis: Hydrate (I-Video) ................................. 284
Lesson 4 Synopsis: Specific Heat (I-Video) ......................... 285
Lesson 5 Synopsis: Le Chatelier’s Principle (I-Video) ............ 285
Video Task Analysis for Each Lesson .................................. 286
Lesson 1 Analysis: Flame Test (N-Video) .............................. 288
Lesson 2 Analysis: Solubility and Precipitation (N-Video) ...... 291
Lesson 3 Analysis: Hydrate (I-Video) ................................. 295
Lesson 4 Analysis: Specific Heat (I-Video) ......................... 299
<table>
<thead>
<tr>
<th>Chapter 10 Cross-Case Analysis</th>
<th>320</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparison of Demographics and School Resources</td>
<td>320</td>
</tr>
<tr>
<td>Comparison of Laboratory Lessons between Schools</td>
<td>322</td>
</tr>
<tr>
<td>Comparison of Student/Teacher Interviews</td>
<td>324</td>
</tr>
<tr>
<td>Comparison of SAI II Results</td>
<td>326</td>
</tr>
<tr>
<td>Comparison of Video Task Analyses</td>
<td>330</td>
</tr>
<tr>
<td>Comparison of Graphic Analyses of Video Data</td>
<td>333</td>
</tr>
<tr>
<td>Comparison of Video Analysis Rubric Results</td>
<td>338</td>
</tr>
<tr>
<td>Summary</td>
<td>345</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 11 Discussion and Implications</th>
<th>348</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support for the Hypotheses and Causal Map</td>
<td>348</td>
</tr>
<tr>
<td>Implications for Teaching</td>
<td>350</td>
</tr>
<tr>
<td>Limitations of the Study</td>
<td>353</td>
</tr>
<tr>
<td>The Hypotheses</td>
<td>353</td>
</tr>
<tr>
<td>The Data Collection Instruments</td>
<td>353</td>
</tr>
<tr>
<td>Student and Teacher Pre/Post Interviews</td>
<td>354</td>
</tr>
<tr>
<td>Scientific Attitude Inventory II</td>
<td>354</td>
</tr>
<tr>
<td>Audiovisual Recordings</td>
<td>357</td>
</tr>
<tr>
<td>Transcript Analyses</td>
<td>358</td>
</tr>
<tr>
<td>Video Analysis Rubric</td>
<td>359</td>
</tr>
<tr>
<td>ILAB Tool Training and Implementation</td>
<td>359</td>
</tr>
<tr>
<td>Color Recognition Technology</td>
<td>360</td>
</tr>
<tr>
<td>Design of Study</td>
<td>360</td>
</tr>
<tr>
<td>Future Research</td>
<td>361</td>
</tr>
<tr>
<td>Potential Improvements to the ILAB Study</td>
<td>362</td>
</tr>
<tr>
<td>Future of the ILAB Tools</td>
<td>364</td>
</tr>
<tr>
<td>Conclusions</td>
<td>365</td>
</tr>
</tbody>
</table>

| References | 368 |

| Appendix A About the Investigator | 384 |

| Appendix B Approved Consent Forms | 387 |
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1-1</td>
<td>Causal Map of This Study</td>
<td>10</td>
</tr>
<tr>
<td>Figure 5-1</td>
<td>Monitoring color change during a chemical reaction using the SALS and a lightbox</td>
<td>141</td>
</tr>
<tr>
<td>Figure 5-2</td>
<td>A simple ionic conductivity probe (consisting of two insulated wires exposed at the tip with a gap between them) can be used with the SALS control box to convert conductivity to audible pitch</td>
<td>143</td>
</tr>
<tr>
<td>Figure 5-3</td>
<td>The CALS control box with a test tube probe (left) and a solids probe (right)</td>
<td>144</td>
</tr>
<tr>
<td>Figure 5-4</td>
<td>A notched syringe (left) and a float with tactile glue markers in a 50 mL graduated cylinder (right) are used for measuring liquid volumes</td>
<td>146</td>
</tr>
<tr>
<td>Figure 5-5</td>
<td>A properly designed laboratory bench is one of the most important elements of safe and effective laboratory practice for students with BLV</td>
<td>147</td>
</tr>
<tr>
<td>Figure 6-1</td>
<td>Percent of Time Engaged During N-Video Lab Sessions for BLV Student and Sighted Partner</td>
<td>185</td>
</tr>
<tr>
<td>Figure 6-2</td>
<td>Percent of Time Engaged During I-Video Lab Sessions for BLV Student and Sighted Partner</td>
<td>185</td>
</tr>
<tr>
<td>Figure 7-1</td>
<td>Percent of Time Engaged During N-Video Lab Sessions for BLV Student and Sighted Partner</td>
<td>226</td>
</tr>
<tr>
<td>Figure 7-2</td>
<td>Percent of Time Engaged During I-Video Lab Sessions for BLV Student and Sighted Partner</td>
<td>226</td>
</tr>
<tr>
<td>Figure 8-1</td>
<td>Percent of Time Engaged During N-Video Lab Sessions for BLV Student and Sighted Partner</td>
<td>266</td>
</tr>
<tr>
<td>Figure 8-2</td>
<td>Percent of Time Engaged During I-Video Lab Sessions for BLV Student and Sighted Partner</td>
<td>266</td>
</tr>
<tr>
<td>Figure 9-1</td>
<td>Percent of Time Engaged During N-Video Lab Sessions for BLV Student and Sighted Partner</td>
<td>310</td>
</tr>
<tr>
<td>Figure 9-2</td>
<td>Percent of Time Engaged During I-Video Lab Sessions for BLV Student and Sighted Partner</td>
<td>310</td>
</tr>
</tbody>
</table>
Figure 10-1  Percent of Time Engaged During N-Video Lab Lessons for BLV Students and Sighted Partners .................................................... 334

Figure 10-2  Percent of Time Engaged During I-Video Lab Lessons for BLV Students and Sighted Partners .................................................... 334

Figure 10-3  Overall Percentages of Time Engaged During N-Video Lab Lessons and I-Video Lab Lessons for BLV Students and Sighted Partners ..... 338
LIST OF TABLES

Table 1-1 Hypotheses for This Study ................................................................. 8
Table 4-1 Pre-School-Year Student Interview Questions ................................. 108
Table 4-2 Post-School-Year Student Interview Questions ................................. 108
Table 4-3 Post-School-Year Teacher Interview Questions ................................ 110
Table 4-4 The 40 Questions of the Scientific Attitude Inventory II as Administered to ILAB Study Participants .................................................... 113
Table 4-5 Video Analysis Rubric Used by Investigator, External Evaluator, and Independent Rater for Each Video in Data Set ................................... 120
Table 4-6 Variables and Their Descriptions ....................................................... 127
Table 6-1 SAI II Data for Nate, Pre/Post School Year 2007-08 ........................ 159
Table 6-2 Lesson 1 Video Task Analysis ............................................................. 165
Table 6-3 Lesson 2 Video Task Analysis ............................................................. 170
Table 6-4 Lesson 3 Video Task Analysis ............................................................. 173
Table 6-5 Lesson 4 Video Task Analysis ............................................................. 176
Table 6-6 Lesson 5 Video Task Analysis ............................................................. 179
Table 6-7 Video Analysis Rubric Results .......................................................... 186
Table 6-8 Patterns Observed with the Video Analysis Rubric ......................... 187
Table 7-1 SAI II Data for Ryan, Pre/Post School Year 2007-08 ....................... 200
Table 7-2 Lesson 1 Video Task Analysis ............................................................. 206
Table 7-3 Lesson 2 Video Task Analysis ............................................................. 208
Table 7-4 Lesson 3 Video Task Analysis ............................................................. 213
Table 7-5 Lesson 4 Video Task Analysis ............................................................. 216
Table 7-6 Lesson 5 Video Task Analysis ............................................................. 221
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-7</td>
<td>Video Analysis Rubric Results</td>
<td>227</td>
</tr>
<tr>
<td>7-8</td>
<td>Patterns Observed with the Video Analysis Rubric</td>
<td>228</td>
</tr>
<tr>
<td>8-1</td>
<td>SAI II Data for Neil, Pre/Post School Year 2007-08</td>
<td>242</td>
</tr>
<tr>
<td>8-2</td>
<td>Lesson 1 Video Task Analysis</td>
<td>249</td>
</tr>
<tr>
<td>8-3</td>
<td>Lesson 2 Video Task Analysis</td>
<td>251</td>
</tr>
<tr>
<td>8-4</td>
<td>Lesson 3 Video Task Analysis</td>
<td>254</td>
</tr>
<tr>
<td>8-5</td>
<td>Lesson 4 Video Task Analysis</td>
<td>257</td>
</tr>
<tr>
<td>8-6</td>
<td>Lesson 5 Video Task Analysis</td>
<td>260</td>
</tr>
<tr>
<td>8-7</td>
<td>Video Analysis Rubric Results</td>
<td>267</td>
</tr>
<tr>
<td>8-8</td>
<td>Patterns Observed with the Video Analysis Rubric</td>
<td>268</td>
</tr>
<tr>
<td>9-1</td>
<td>SAI II Data for Emily, Pre/Post School Year 2007-08</td>
<td>282</td>
</tr>
<tr>
<td>9-2</td>
<td>Lesson 1 Video Task Analysis</td>
<td>288</td>
</tr>
<tr>
<td>9-3</td>
<td>Lesson 2 Video Task Analysis</td>
<td>291</td>
</tr>
<tr>
<td>9-4</td>
<td>Lesson 3 Video Task Analysis</td>
<td>295</td>
</tr>
<tr>
<td>9-5</td>
<td>Lesson 4 Video Task Analysis</td>
<td>299</td>
</tr>
<tr>
<td>9-6</td>
<td>Lesson 5 Video Task Analysis</td>
<td>304</td>
</tr>
<tr>
<td>9-7</td>
<td>Video Analysis Rubric Results</td>
<td>311</td>
</tr>
<tr>
<td>9-8</td>
<td>Patterns Observed with the Video Analysis Rubric</td>
<td>312</td>
</tr>
<tr>
<td>10-1</td>
<td>Demographic Information for the Four Schools</td>
<td>321</td>
</tr>
<tr>
<td>10-2</td>
<td>Laboratory Lessons for the Four Schools</td>
<td>323</td>
</tr>
<tr>
<td>10-3</td>
<td>Comparison of SAI II Scores</td>
<td>327</td>
</tr>
<tr>
<td>10-4</td>
<td>Paired Sample T-Tests and Permutation Tests with Bonferroni Correction</td>
<td>329</td>
</tr>
<tr>
<td>10-5</td>
<td>Interpretation of Fleiss’ Kappa Coefficients</td>
<td>339</td>
</tr>
<tr>
<td>Table 10-6</td>
<td>Inter-Rater Reliability Kappa Coefficients</td>
<td>340</td>
</tr>
<tr>
<td>------------</td>
<td>------------------------------------------</td>
<td>-----</td>
</tr>
<tr>
<td>Table 10-7</td>
<td>Averaged Group N-Lesson and I-Lesson Rubric Scores</td>
<td>343</td>
</tr>
</tbody>
</table>
### ABBREVIATIONS USED IN ILAB WORK

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADA</td>
<td>Americans with Disabilities Act</td>
</tr>
<tr>
<td>AP</td>
<td>advanced placement, used to refer to high school courses that are eligible for college credit</td>
</tr>
<tr>
<td>AVI</td>
<td>Audio Video Interleave, a Microsoft multimedia container format</td>
</tr>
<tr>
<td>BLV</td>
<td>blind or low vision</td>
</tr>
<tr>
<td>BT Donald</td>
<td>Badger teacher Donald</td>
</tr>
<tr>
<td>CALS</td>
<td>Color Analysis Laboratory Sensor, a device developed by ILAB</td>
</tr>
<tr>
<td>DF</td>
<td>degrees of freedom, used in statistical analyses</td>
</tr>
<tr>
<td>HT April</td>
<td>Highland teacher April</td>
</tr>
<tr>
<td>I-Lesson</td>
<td>lesson incorporating ILAB tool use</td>
</tr>
<tr>
<td>I-Video</td>
<td>video of lesson incorporating ILAB tool use</td>
</tr>
<tr>
<td>IDEA</td>
<td>Individuals with Disabilities Education Act</td>
</tr>
<tr>
<td>ILAB</td>
<td>Independent Laboratory Access for the Blind</td>
</tr>
<tr>
<td>IRB</td>
<td>Institutional Review Board in Penn State’s Office of Research Protections</td>
</tr>
<tr>
<td>JAWS</td>
<td>Job Access with Speech, a text-to-speech computer screen-reader package enabling persons with BLV to access information on computer screens</td>
</tr>
<tr>
<td>N-Lesson</td>
<td>lesson not incorporating ILAB tool use</td>
</tr>
<tr>
<td>N-Video</td>
<td>video of lesson not incorporating ILAB tool use</td>
</tr>
<tr>
<td>NCBYS</td>
<td>National Center for Blind Youth in Science, part of NFB Jernigan Institute</td>
</tr>
<tr>
<td>NFB</td>
<td>National Federation of the Blind</td>
</tr>
<tr>
<td>NSEC</td>
<td>Nanoscale Science and Engineering Center, at University of Wisconsin-Madison</td>
</tr>
<tr>
<td>NSF</td>
<td>National Science Foundation</td>
</tr>
</tbody>
</table>
ORP  Office of Research Protections at The Pennsylvania State University

PTE  percent of time engaged in performing laboratory-goal-directed actions during laboratory lessons

RDE  Research in Disabilities Education, a funding category of the National Science Foundation

RGB  red-green-blue, the three additive primary colors

RT Nancy  Rollinsville teacher Nancy

SAI II  Scientific Attitude Inventory II

SALS  Submersible Audible Light Sensor, a device developed by ILAB

SAVI/SELPH  Science Activities for the Visually Impaired/Science Enrichment for Learners with Physical Handicaps, a curriculum developed for BLV students at UC-Berkeley’s Lawrence Hall of Science

SPSS  Statistical Package for the Social Sciences, statistical analysis software

STEM  science, technology, engineering, and mathematics

STS  Scientific Talking Stopwatch, a device developed by ILAB

TT Lindsey  Twin Pines teacher Lindsey

VSEPR  valence shell electron-pair repulsion
Acknowledgements

I would like to acknowledge a number of people who have had a significant impact on my growth and development both as a person and as a scientist. First I would like to thank my parents, Ron and April Supalo, for all their love and support throughout my long academic career. Their patience with me as I progressed through school and their encouragement to pursue my dreams of becoming a chemist were invaluable. I would also like to thank all my brothers and sisters and other family members for their love and continued support over the years. Never once did they say I should not be a scientist because I am blind. For this I am deeply grateful.

My research adviser, Tom Mallouk, provided me the opportunity to join his group during my first semester at Penn State University. He taught me how to ask scientific questions, write scientific papers, and formulate research proposals, all of which was essential to my professional development. His patience with me as I sought my place in the scientific community was commendable. I would also like to thank the members of the Mallouk research group for their years of encouragement and assistance in the laboratory.

Bill Carlsen, the committee member from Penn State’s Department of Curriculum and Instruction, provided continued guidance in helping me learn to design and qualitatively analyze science education questions, despite his busy schedule. I am also greatly appreciative for the vital input of Chemistry Department committee members Karl Mueller and Mark Maroncelli, and other faculty members who served on my committee in one form or another over the years.
George Bodner, Distinguished Professor of Chemistry and Education from Purdue University, who served as a special member of my committee, willingly met with me on a regular basis and generously provided his valuable insights on conducting chemical education research.

James Broyles, executive officer in the Department of Chemistry and my friend, helped me with the department’s financial support for the undergraduate workers who assisted me over the years.

Dave Wohlers, a blind professor of chemistry at Truman State University, has served as one of my mentors since we first met at Purdue in fall 1995. He was proof to me that I could become a scientist and was my inspiration.

The commitment of Dave and Christine Vernier, and Vernier Software & Technology, to the ILAB project and their strong desire to empower blind and low-vision students to access STEM education was – and still is – admirable. Their offering discounts on hardware and software, and later having their software engineers incorporate accessibility features directly into the source code of Logger Pro, demonstrated a level of dedication unparalleled by any other company collaborating with ILAB. This strong relationship has led to other projects, such as the talking LabQuest, and serious discussions about revolutionary developments for science, technology, engineering, and mathematics (STEM) accessibility for the blind in the near future and beyond. I give my highest commendation to the Verniers for their support of me and the ILAB project.

My close friends Marilyn Winograd and Lillian Rankel worked countless hours with me on constructing low-tech ways for blind students to access science laboratory classrooms. Lillian welcomed me into her home on numerous occasions when conducting
ILAB-related work and helped me prepare for my oral comprehensive exam. Their support of my passion to help blind students learn science was very gratifying and validating.

I would also like to thank all my lab technicians and readers for their countless hours of diligent hard work. The lab techs assisted me with experiments and analysis, often coming to the lab on late nights and weekends as needed. The readers assisted with accessing my course and research-related materials, and conducted library and online literature searches. These people helped me grow my knowledge base and understanding of science and science education.

I would like to give special thanks to Jennifer Humphrey for her many hours of helping me prepare and edit this dissertation. Without her expertise, I would not have become a better writer.

Additionally, the instructors and staff members at Blindness: Learning in New Dimensions, Inc., in Minneapolis, provided me the opportunity to polish my blindness skills in 1995, 1996, and 2003. They taught me to read Braille at a decent speed and to use it competently when giving oral presentations. My cane travel instructors taught me that blind people truly can learn to navigate in unfamiliar environments and not be afraid. The computer instructor helped me learn e-mail, Internet, and word processing skills. The home management instructor taught me how to cook and clean and gave me the confidence to handle cooking equipment. All these experiences fostered the self-reliance and skill to conquer any challenge that comes my way.

My friends in the National Federation of the Blind are like my extended family. They taught me that blind people can do anything they put their minds to. They also
taught me the networking skills to seek new opportunities and to mentor other blind students pursuing their own academic endeavors.

The National Science Foundation provided most of the funding for the ILAB project, under grant numbers HRD-RDE 0726417 and HRD-RDE 0435656. With this support, ILAB has been able to touch many lives. Also, the people I met through NSF’s Research in Disabilities Education program galvanized me to continue my work to empower blind persons in STEM education.

I would also like to acknowledge all the students, parents, teachers, and schools that participated in the ILAB project. Without their willingness to participate, this study would not have been possible.

Finally, I will always remember my friends Fred Leader, Nicholas Schmittroth, and Dr. Betsy Zaborowski. Fred and Nick both spent time with me during my undergraduate years and early years of graduate school. We talked about scientific questions and just why the world was the way it was, and how we could make things better. Betsy encouraged me to aim for the door of opportunity and to be persistent in my graduate studies. All three are sorely missed.
Chapter 1

Introduction to the Problem

Very few blind and low-vision students have successfully been educated in science in primary, secondary, and post-secondary institutions across the United States and around the world. BLV students are an underrepresented population in science education as a result of technological and attitudinal barriers to equal access in the science classroom. This lack of sufficient educational opportunities for students with blindness and low vision (BLV) has led to low participation in the professional scientific community.

A report from the National Federation of the Blind Jernigan Institute (2006) stated: “Historically, academic and vocational expectations for blind students, with few exceptions, have neither elicited nor supported high academic performance. The majority of these blind students have received especially inadequate training in science and math concepts, particularly during the critical middle and high school years, when a passion for a subject and career interest is best sparked.”

The Independent Laboratory Access for the Blind (ILAB) project, developed at The Pennsylvania State University, designed tools and techniques to allow BLV students in mainstream high schools and residential schools for the blind to independently carry out physical science laboratory experiments on a basis equivalent to that of their sighted counterparts. The goal was to foster their interest in science and to possibly inspire them to consider careers in science, technology, engineering, and mathematics (STEM).
Background

According to the Social Security Act (1986), statutory blindness is defined as central acuity of corrected 20/200 or less, or visual field of 20 degrees or less. Low vision, as defined by Corn (1983) and cited in Bishop (2004), is “a severe impediment after correction, but the potential exists for the use of available vision.”

Over many decades, BLV students have entered a wide variety of career fields, including education, law, social work, and computer science; however, there are much smaller proportions of blind students pursuing studies in the physical sciences. Census 2000 (Waldrop and Stern, 2003) found that, excluding persons in institutions, 19.3% of the U.S. population had a disability. As cited in Woods et al. (1996, p. 4) and Miner et al. (2001, p. 4), census data from 1990 indicated that while people with disabilities represented approximately 10.4% of the overall workforce, they made up only 2.7% of the science and engineering workforce. National Science Foundation (2003) figures indicated that 6% of persons working in the sciences or engineering were disabled. Regardless of the varying specifics of the numbers, these data sets clearly indicate a substantial underrepresentation of persons with disabilities in STEM.

The figures for chemists are even lower, particularly for those who are visually impaired. While Working Chemists with Disabilities: Expanding Opportunities in Science (Woods et al., 1996) spotlighted 17 professional chemists with a wide range of disabilities including blindness, chemists with BLV are very few in numbers. According to the 2009 annual employment survey conducted by the American Chemical Society, in which a large sample of its non-student and non-retired U.S. membership was asked for the first time if they considered themselves to be disabled, only 2.2% of the participants
indicated a positive response (Allum, in press). It stands to reason that those who are visually disabled represent just a small proportion of that 2.2%. More specific employment numbers can be found in the 1995 Resource Directory of Scientists and Engineers with Disabilities, published by the American Association for the Advancement of Science (Stern and Summers, 1995), which listed 98 individuals with disabilities who were working in chemistry-related positions, only nine of whom were identified as having blindness or low vision.

While many factors inform the career choices of students with BLV, the lack of independent, fulfilling experiences in science laboratory classrooms is a major impediment to learning and becoming deeply interested in science, as stated or implied by numerous researchers (e.g., French, 1924; Rutherford and Ahlgren, 1990; Fraser, 2008). Providing appropriate tools and training, while concurrently offering tested resources for teachers of students with BLV, may encourage more students to pursue advanced studies and, ultimately, careers in science (Scadden, 2005). However, traditional techniques have included pairing BLV students with nondisabled counterparts in science laboratory classrooms, thus unfortunately encouraging a passive approach to learning. Even more unfortunate, waivers have often been granted to BLV students, exempting (or prohibiting) them from participating in science courses.

In order to prevent discrimination against disabled individuals and uphold their equal participation in society, the U.S. Congress established a legal framework to make access possible to a full range of educational opportunities for persons with disabilities. These laws include the Rehabilitation Act of 1973; Education for All Handicapped Children Act of 1975, later renamed the Individuals with Disabilities Education Act
(IDEA); amendments to IDEA in 1997 and 2004; Americans with Disabilities Act (ADA) of 1990; and the No Child Left Behind Act of 2002 (Turnbull et al., 2006; Wright and Wright, 2005; Murdick et al., 2007; Yell, 2006; Ysseldyke and Algozzine, 2006).

Educators have a defined set of obligations to students with disabilities under these laws. These students can request modifications, accommodations, and auxiliary aides to more equitably participate in all educational programs and activities, further developing the barrier-free, fully inclusive environment specified by Congress. Full inclusion in society was called “integrationism” by tenBroek (1966, p. 843), who defined the term as “a policy entitling the disabled to full participation in the life of the community and encouraging and enabling them to do so.”

Residential schools for the blind have provided educational services to students with BLV for nearly 200 years (Matson, 1990; Mellor, 2007). However, research has shown that students with BLV who learn in regular classrooms often perform better than their counterparts enrolled in schools for the blind (Ferguson and Asch, 1989; Barraga, 1990; Baker et al., 1994/95). One of the earliest efforts to mainstream students with BLV into public schools occurred in Chicago in 1906, which was followed by numerous similar efforts across the U.S. (Mellor, 2007). In 1975, the passage of the Education for All Handicapped Children Act furthered the paradigm of taking students with BLV out of schools for the blind and placing them in mainstream schools (Mellor, 2007; Miner et al., 2001). The core purpose was to achieve educational incorporation of students with disabilities into regular classrooms, including science laboratory classrooms, alongside their nondisabled peers.
While studying outside the physical sciences is a fairly common choice for blind college students, it is important to note that most fields require introductory biology, physics, and chemistry classes, most of which include laboratory components. However, Stefanich and Norman (1996) observed in a national study that most elementary and high school science teachers and college science educators have little or no direct experience in teaching students with disabilities and may possess stereotypical views concerning these students’ potential for achievement. Similarly, Barraga (1990) noted that one of the main challenges in personnel preparation for teaching students with BLV is teachers’ insufficient knowledge in applying current best practices in classrooms. These situations are not in the students’ best interests because many science courses are gateways to numerous professional opportunities, including those in STEM.

**Introduction to ILAB**

As Day (1995) recommended, students with BLV should be provided with blindness skills training toward the goal of independently learning and functioning in a sight-centered world with minimal sighted assistance. Incorporating adaptive materials into the typical science curriculum may allow BLV students to have a laboratory experience similar to that of their sighted counterparts. Mayo (2007) conducted a research project in critical theory to evaluate how students with BLV process abstract visual concepts in chemistry, such as diagrams meant to represent three-dimensional constructs. Mayo’s research was conducted toward the goal of achieving an emancipatory experience for BLV students in chemistry classes – in other words, to help these students have the equal opportunity to pursue STEM education. Critical theory deals with aspects
relating power and authority to social equality. This emancipatory view of the blind in science can be further extended to the ILAB work through the creation of talking and audible tools to empower BLV students in science laboratory classrooms.

The Independent Laboratory Access for the Blind (ILAB) project was founded on the premise that hands-on, multisensory science learning through the use of adaptive/assistive technologies can help facilitate educational achievement and an ongoing interest in science for secondary-school students with BLV.

As Piaget (1970, p. 51) pointed out, simply observing someone performing a science demonstration does not necessarily result in learning, and surely does not excite the spirit of exploration and discovery. He stated, “… a sufficient experimental training was believed to have been provided as long as the student had been introduced to the results of past experiments or had been allowed to watch demonstration experiments conducted by his teacher, as though it were possible to sit in rows on a wharf and learn to swim merely by watching grown-up swimmers in the water.”

For BLV students to “learn to swim” in science laboratories, assistive technologies are necessary. The term assistive (or access or adaptive) technology refers to specialized devices designed for persons with disabilities to allow them to perform specific tasks or carry out specific functions. These technologies are designed to facilitate full inclusion, both in the classroom and in society (Horejsi, 2003). Assistive educational technologies can include any devices designed or modified to help convey concepts to students with disabilities. These tools include both low-tech and high-tech items (Watson and Johnston, 2007; Supalo et al., 2008).
The ILAB project developed and tested various adaptive tools, technologies, and methodologies to enable students with BLV to perform independently in chemistry and physics laboratories (Supalo, 2007). These items included high-tech approaches such as software and hardware as well as low-tech laboratory equipment. The ILAB software and hardware primarily consisted of speaking tools and other audible devices (Supalo et al., 2007). The line of Vernier Software & Technology laboratory probes, in conjunction with the Logger Pro 3.8 data-collection software package, was successfully interfaced with the Job Access with Speech (JAWS) text-to-speech computer screen-reader package, thus allowing a screen-reader program to relate all data displayed on Logger Pro.

Complementing these software tools were new hardware tools including the Color Analysis Laboratory Sensor, the Submersible Audible Light Sensor (Supalo et al., 2006; Supalo et al., 2007), and the Scientific Talking Stopwatch.

These tools were initially tested at a residential school for the blind, and then later expanded into 11 mainstream secondary schools and two additional schools for the blind. Field testing was conducted of the ILAB tools and modified curricula as the participating BLV students progressed through high school. Data from the four participating mainstream schools in 2007-08 are included in this report. A detailed assessment of skills, tool incorporation into curricula, and social interactions between the students with BLV and their sighted counterparts was conducted, and attitudinal outcomes were measured by comparing the results from the BLV students before and after their participation in the ILAB project.

The hypotheses for this study are stated in Table 1-1.
The investigator predicted that having the use of new access technologies such as those from ILAB to assist BLV students in science laboratory classrooms, along with the proper training to use them, would lead to a more hands-on laboratory experience. The investigator also predicted that the hands-on ILAB experience in science laboratory classrooms would lead to an interconnected network of benefits for BLV students, including increased interest in science, participation in lab activities involving significant contributions to the completion of lab goals, understanding of scientific concepts, academic achievement, peer acceptance into lab groups, and entry into the STEM professions. The interconnected relationships are illustrated in Figure 1-1, the causal map.
of this study. As shown in the causal map, BLV students can achieve interest in science and entry into STEM careers either with or without access technologies. However, the number of BLV students choosing to pursue the STEM professions is very small. As shown, implementing access technologies in science laboratory classrooms to allow BLV students to assume greater roles in their lab groups should enhance their experience of science and promote greater interest in STEM career paths.

The multisensory learning experiences designed for BLV students may also assist nondisabled students in the learning process by providing alternative channels of acquiring information. Thus, tools such as those developed by ILAB could potentially impact a broad spectrum of students who otherwise might be unlikely to undertake laboratory sciences in college or ultimately choose careers in STEM.

This study also demonstrates to science educators the capabilities of ILAB tools and illustrates how these tools can be incorporated into science curricula.
Lab Experience and Participation

**Without assistive technology**
- **ROLES:** limited to reader/recorder
- **ROUTINES:** redundant data collections from more than one person, less involved with set-up and clean-up, less involved with going and getting materials
- **SHARED SENSE OF PURPOSE:** diminished

**With assistive technology**
- **ROLES:** could be reader/recorder, but also could be data collector, equipment manipulator, report writer, problem solver, troubleshooter
- **ROUTINES:** non-redundant data collection, more involved with set-up, clean-up, and getting materials
- **SHARED SENSE OF PURPOSE:** not diminished

Participation and Understanding

- Decreased
- Increased

Acceptance/Achievement/Interest in Science

- Decreased
- Increased

**Choice of STEM Career

Figure 1-1: Causal Map of This Study
Inclusion in Scientific Communities of Practice

According to Wenger (1998) and Lave and Wenger (1991), a community of practice is a group of persons mutually engaged in an enterprise and utilizing a shared repertoire to achieve a common goal. Communities of practice can vary in size and location. Becoming a member of a specific community of practice requires a certain level of expertise. Prior to full inclusion, individuals can participate as apprentices on the periphery of the community of practice while learning necessary skills from their more qualified counterparts. This concept was referred to as “legitimate peripheral participation” by Lave and Wenger (1991). This learning process is often performed with the expectation that the peripheral individuals will advance to full membership at a later date once certain criteria have been met.

Various researchers have applied Lave and Wenger’s concept of community of practice to scientists and the sciences (e.g., Eisenhart, 1994; Kozma et al., 2000; Sims, 2005) and to how students may progress into full membership in the scientific community (e.g., Hogan and Corey, 2001; Macklin, 2007; O’Neill, 2001). One particularly well-documented example of a scientific community of practice can be found in Latour and Woolgar (1986), which illustrated how a group of professional scientists worked together as a team in constructing knowledge to solve a problem.

The concept of community of practice can be extended to students in laboratory groups. It is the belief of the investigator that use of the ILAB tools in science laboratory classrooms, under the guidance of an expert teacher providing instruction in the form of hands-on activities, may encourage some BLV students to pursue full membership in the communities of practice represented by their lab groups. Later, some of these students
may seek additional education from members of the scientific community to proceed to eventual full membership in the scientific professions.

**Overcoming the Barriers**

In the experience of the investigator, who has been totally blind since early childhood (see Appendix A, titled “About the Investigator”), BLV students generally find it difficult to fully integrate as equal participants in the communities of practice represented by secondary-school laboratory groups. BLV students face barriers in advancing beyond peripheral roles in their scientific communities of practice as a result of numerous factors, including but not limited to:

1. A lack of access technologies to assist them in the laboratory.
2. The directed laboratory assistant approach to conducting scientific activities.
3. The social paradigm influencing sighted students, science educators, and school administrators to prohibit BLV student involvement.
4. Fear of injury in the laboratory.

As discussed by Scadden (2005), a lack of access technologies in science classrooms is a major barrier to students with BLV when it comes to entering the STEM professions. Instead, BLV students traditionally are paired with sighted persons in laboratory activities, who operate under the direction of the BLV students, acting as their hands to conduct tasks and eyes to see and describe what happens during experiments. This is referred to as the “directed laboratory assistant” approach (Miner et al., 2001, p. 62). Assistants are to do only what the BLV students tell them to do, except when the directed tasks present substantial safety risks to the students, assistants, or other people
present. Therefore, assistants must be well-versed in safety protocol. The directed laboratory assistant approach is often overused or misused, such as when the assistant performs tasks without being directed by the BLV student to do so and may even perform the entire experiment while providing verbal descriptions.

However, it is the assertion of the investigator that, even when the directed laboratory assistant approach is employed as intended, it has serious shortcomings. While this passive (and peripheral) approach helps fulfill academic requirements for BLV students and safeguards them from injury in the laboratory, it denies them the pleasures and intellectual stimulation of experiencing science firsthand and of being full members in their communities of practice. This traditional approach does not tend to build BLV students’ confidence in their own capabilities to do laboratory work or their interest in the STEM pipeline. Being insulated from actually doing lab work can even make them afraid of manipulating laboratory equipment and materials, further reducing their self-confidence and interest in science. Increasing the level of involvement of BLV students in laboratory tasks and membership in their lab groups by means of access technologies could have a substantial positive effect on their interest in science.

Many in the blind community feel that the major problem of blindness is not the inability to see, but rather the general public perception of persons with blindness (Jernigan, 1965). Sighted classmates, teachers, school administrators, and parents may have various preconceived notions as to BLV students’ abilities to manipulate equipment and materials in laboratory classes. Some of these views can negatively impact BLV students’ amount of hands-on involvement. Providing a more hands-on laboratory experience via access technologies may help educate sighted classmates, teachers, and
other interested parties, as well as the BLV students themselves, regarding the actual capabilities of these students and further raise expectations for their participation in science activities. This may lead to greater success in the classroom for students with BLV and increased interest and self-confidence in performing science activities (Rutherford and Ahlgren, 1990; McPhail et al., 2000; Reynolds, 2004).

Regarding fear of injury, science educators and BLV students may believe these students lack the ability to recognize possible dangers such as lit Bunsen burners, hot plates, chemical spills, and broken glassware. Thus, science educators often limit hands-on involvement and resort to the use of the directed laboratory assistant approach. Refuting this concern, however, Swanson and Steere (1981) cited several studies indicating that persons with disabilities – including those with BLV – faced no greater safety risks in chemistry laboratories than did their nondisabled counterparts.

**Potential Benefits of ILAB**

The ILAB team, through its tool development efforts, created new means by which BLV students can directly collect observations and do statistical analyses in laboratory settings. It was the intent of this study to test the access technologies developed by ILAB to determine if these multisensory tools can increase the level of participation of BLV students in science laboratory groups, with the goal of helping these students toward greater achievement, full membership in their lab groups, and a stronger interest in STEM. The ILAB project also sought to identify a set of best practices, or at least verifiably effective practices, for teaching science to BLV students to be used along with the core set of ILAB tools.
Chapter 2

Review of the Literature on Teaching Science to Blind and Low-Vision Students

A general lack of rigorous research to determine effective means of teaching academic subjects to students with BLV was noted by Barraga (1990), Ferrell (2006), and Wild and Allen (2009). For this review of the literature pertaining to the participation of blind and visually impaired students in science laboratory classes, many case studies as well as papers containing suggestions and tips were found. However, these publications were generally limited in scope as there have been very few research studies done to determine the effectiveness of the suggestions. This is especially problematic in light of the No Child Left Behind Act, which mandates that instruction for all students be grounded in best practices as determined through scientific studies.

Further, Scholl (1969) stated there was a disturbing 30- to 50-year lag between the time of the publication of ideas for teaching scientific concepts to persons who were blind or otherwise print impaired and subsequent documented implementation in science classrooms. Scholl also found it difficult to evaluate the quality and level of effectiveness of published works regarding the education of persons with blindness or low vision. Barraga (1990) likewise noted a substantial time lag between the conducting of research and putting the findings into practice.

The following review of published literature from 1924 to the present provides a background of suggestions, techniques, and technologies for teaching chemistry and other scientific concepts to blind and visually impaired students. In this section, various technologies and tools that were developed for use with blind students are discussed.
Although some of these technologies and tools would be viewed by today’s standards as low-tech solutions, for their time they were cutting-edge innovations. As defined in the *Microsoft Encarta College Dictionary* (2001), the term *low tech* refers to “a simple technology, especially used to make basic items or perform basic tasks,” while *high tech* is defined as “advanced technology and state-of-the-art techniques, especially in electronic engineering” or “using and relating to advanced technological devices and methods.” For the purposes of this dissertation, *low tech* refers to devices that do not require electricity, and *high tech* refers to electronics such as computers, calculators, and laboratory devices such as electronic pH indicators and balances. As succinctly stated by Scholl (1969), children with blindness do not have difficulties with the methodologies of learning but rather with access to suitable educational materials.

**Teaching the Sciences to BLV Students**

R.S. French (1924), then the principal of the California School for the Blind, noted in his “General Science: A Necessary Factor in a Modern Curriculum” the value of science education for students with blindness. Specifically, he discussed the importance of hands-on experiences in science laboratory classrooms for students with BLV, focused perhaps half the time on biology. He discussed how models of plants and animal species could be obtained along with materials in Braille to support a biology curriculum. He also stressed the various ways that students with BLV could participate in meteorology study and physics activities involving inclined planes and balls rolling down a surface. Lastly, he stressed the importance of students with BLV participating in science projects and how these experiences could empower them to develop an interest in science.
Several reports from the American Association of Instructors of the Blind (AAIB) and the journal *The Teachers Forum* in the 1930s illustrate the often strikingly modern and forward-oriented thinking of instructors for BLV students during that era. A general science curriculum designed by a committee of the AAIB was published in 1932, which stimulated new action and many papers by educators of the blind.

Coville (1932), in “Content of a Course in General Science Adapted for Use with the Blind,” advocated for the teaching of general science to blind students to aid their development into adults knowledgeable about scientific matters important in everyday life. She recommended natural specimens for study such as soil samples and plants, and that teachers make the study of science “alive and dynamic” (p. 774). Importantly, she implied that students with blindness were capable of going on to more advanced learning in the sciences and that education in general science could help guide them toward fulfillment of their intellectual potential (p. 775): “[T]he study of general science prepares the foundation for the later study of the special sciences. It determines [the student’s] aptitude for the science electives and guides to an intelligent choice.”

Gibson (1932) likewise wrote about the many benefits of teaching general science to students with blindness in “The Value of General Science to the Blind Child,” including the opportunity to explore interests and talents; the pleasures of learning science; the ability to take care of their own health, sanitation, and home maintenance needs; the elimination of misconceptions; the development and honing of critical thinking abilities; the ability to more knowledgeably participate in their communities (which Gibson referred to in the context of “the duties of citizenship” [p. 773]); and, interestingly, the ability to intelligently contribute to scientific discussions in everyday
social settings. All this was important, stated Gibson, because “We are living in an age of
science” (p. 771) and “science touches the daily life of every individual” (p. 772).

Burke (1932), in “Laboratory Work in Science for the Blind,” claimed that the
greatest need in the field of teaching science to blind students was the development of
appropriate tactile materials. She stated that verbal descriptions were inadequate and
while actual specimens of rocks, plants, and animals were often helpful, they were not
sufficient in many circumstances. For example, the study of flowers, leaves, or roots was
difficult because actual plant matter was often much too small for detailed tactile
exploration. She discussed models borrowed from a local museum, and also models she
constructed herself using clay, cardboard cutouts, and raised illustrations when no other
appropriate tactile materials could be found.

Hamilton (“The Laboratory in Schools for the Blind,” 1932) and Hurst (“Ways
and Means of Teaching General Science to Blind Students,” 1933) also recommended
multisensory approaches to teaching laboratory science to students with BLV. Hamilton
stated that the greatest challenge in teaching science to the blind was finding appropriate
methods for laboratory work. Hamilton believed that the best technique was having the
teacher conduct demonstrations using equipment that could be tactiley explored by the
students and that produced experimental results involving noises such as small explosions
or buzzers whenever possible. Hamilton recognized that commercial adaptations were
few and the quality of improvisations relied on the creativity of individual teachers. The
goal was to achieve high quality education equivalent to that offered in schools for the
sighted.
Hurst discussed various rudimentary adaptations made at a school for the blind for studies in biology, chemistry, and physics. Biology adaptations involved construction materials such as wires, potatoes, cardboard, wrapping paper, and glue, as well as the use of actual specimens such as leaves, branches, and pig or calf hearts. For physics, students learned about switches, sockets, fuses, and light bulbs by examining disassembled, inactivated specimens, then learned to connect the various items to operate devices such as doorbells and small motors. Astronomy models involved representations made with a basketball for the sun and marbles and other small spheres for the planets, and constellations were learned by arranging small cubes. Regarding chemistry, standard laboratory equipment such as flasks, tubing, and stoppers were used, and students were shown how to arrange these items for experiments and dispense chemicals into them. As did Hamilton, Hurst looked forward to a time when students with BLV would have available to them a suite of professionally constructed tools and equipment designed especially for use by the blind.

Also acknowledging that scientific understanding was vital to living in a modern age, Botts (“Our New Course in General Science,” 1934) stated that the most important aspect of teaching science to the blind, and in fact, of teaching science to anyone, was that the teacher strive to establish within students the belief that learning science was possible, pleasurable, and important to having a disciplined and thoughtful mind. Botts emphasized that science education should be customized to the needs of individual students and classes, and that it should include active participation in experiments and demonstrations, models, field trips, class discussions, readings, and individual reports and evaluations.
Hamilton (1934) made a particularly strongly worded case for teaching science to the blind in “What Science Teaching is Advisable in Our High School Departments,” stating that a solid educational background in science is necessary for adults to be capable of critical thinking. “One of the most prolific causes of sloppy thinking and beliefs and prejudices detrimental to effective living is the lack of that habit of mind known as scientific thinking,” Hamilton stated (p. 131). He said that effective learning in science required laboratory work. While Hamilton also claimed that students with BLV might not get as much out of laboratory work as would sighted students but that gaining a little knowledge is better than none, he went on to say that some students with BLV might have serious interests in various scientific disciplines and could go on to professions in the sciences and industrial arts. Sadly, however, Hamilton believed that the study of chemistry by students with BLV was essentially impossible except through presentation of the theories because “in Chemistry so little of the phenomena to be observed is perceptible” to the blind (p. 135).

Koehne (“The Place of Science in the Elementary Curriculum,” 1934) agreed that learning science in school was necessary for students to be able to develop into adults not filled with superstitions and misconceptions, particularly since science was integral to everyday life. She discussed how the Indiana School for Blind, where she was an instructor, focused science learning on the study of health, plants, animals, and food, beginning as early as first grade and advancing in sophistication as children progressed throughout the following grades. She also stated that teaching chemistry was commonly advised against in the higher elementary grades within schools for the blind because the subject was thought to be too difficult for the students.
The 35th Biennial Convention of the American Association of Instructors of the Blind in 1940 resulted in numerous interesting papers and presentations by instructors of the blind, including Long (“The Importance of a Laboratory in Science Classes – What Shall Be in It?” 1940), Peterson (“The Extent and Importance of Laboratory Work in Biology Classes,” 1940), and Waterhouse (“Enrichment through Models,” 1940).

Long was a strong proponent of laboratory instruction in the sciences for students in junior and senior high schools and believed that laboratory classrooms for the blind should have all the science equipment found in any fine school, but specifically adapted for students with BLV as much as possible. Peterson stressed the value of adapted laboratory instruction in biology within schools for the blind, and pointed out that a few students with BLV who had been educated in mainstream schools and colleges had already proven it was possible for the blind to learn biology with excellent results. Peterson stated that the study of natural science in schools for the blind was “long on theory and short on practice” (p. 159) and that this situation needed to be changed through the incorporation of real materials from the natural environment. He said that instructors’ “faith in the inherent ability of the blind” to learn science had increased in recent years, and that it was important to discard preconceived ideas of the capabilities of students with blindness (p. 159). Waterhouse advocated the use of tactile models made specifically for the learning needs of students with BLV, but preferred the use of actual materials when practical and available. He stated that models could spare students lengthy verbal explanations of dubious value, and that learning would be better retained by having students assemble models of complex objects to gain an understanding of how the parts fit together.
Bryan (1941), in “Science for the Blind,” described how students with blindness were welcome to enroll in a range of science classes and were regarded as equals at a mainstream public high school in Baltimore, Maryland. Classes included general science, chemistry, physics, and biology. Students with BLV participated in the same laboratory experiments as did their classmates, were expected to set up laboratory equipment and observe experimental results, and often assumed leadership roles in classes and lab groups. Traditional instruction in chemistry was supplemented with the use of tactile models and all senses other than sight.

Insightful presentations by Heisler (1946), Overbeay (1946), Riddle (1946), and many others resulted from the 38th Meeting of the American Association of Instructors of the Blind. Heisler (“The Need for Three Dimensional Instruction in Science Curricula”) discussed several types of multisensory instructional aids, including verbal descriptions, embossed diagrams, tactile models (analogical, small-scale, large-scale, and full-scale), auditory recordings, preserved animal specimens, natural specimens of minerals and soil, and live specimens of plants and animals. Overbeay (“Enriching and Extending the Science Program to Meet Post-War Needs”) claimed that science was being neglected in schools for the blind and that a fundamental knowledge of science was necessary to prepare students for participation as citizens in a post-War democratic society. He believed that the scientific advances of World War II were stimulating the expansion of the study of science, and that the sciences should be taught continuously to students with blindness from the very earliest grades up through high school. Riddle (“Science in the Elementary Grades”), who believed that increased study in science could reduce the risk of future wars, stated that various aspects of learning were impossible for
students with blindness without direct, physical experience with tangible objects. He claimed verbal descriptions were inadequate, and that educational progress was impeded when any child was unable to understand fundamental concepts due to a lack of contact with concrete objects.

Like many before her, Pease (1946) pointed out that, to become functioning members of a modern society, students with blindness required multisensory science education from their earliest days in school and continuing throughout the grades. While she mostly focused on using the outdoors as a nature laboratory in “The Science Laboratory in the Elementary School for the Blind,” she also stated that the selection and purchase of indoor laboratory equipment for experimentation must be carefully based on its appropriateness for use by the blind. Pease did not, however, offer any specific suggestions on such equipment, but said that teachers must use their ingenuity to offer meaningful science instruction.

Bryan’s “General Science for the Blind” (1957) outlined simple experiments that high school students with visual impairments could perform in general science courses. This program adapted science instruction to allow students to use senses other than sight for making observations. This work stressed the use of tactile models and diagrams and encouraged educators to require students to record experiments in a Braille notebook. Several suggested experiments were those involving air, water, convection currents, dew point, thermometry, weather, biology, zoology, and human physiology. Tactile observation of all demonstration apparatus was, according to Bryan, the “one general pedagogical rule for blind science instruction.”
Publications outlining more sophisticated technological and instructional adaptations for teaching science to students with BLV later appeared, such as Franks and Sanford’s (1976) “Using the Light Sensor to Introduce Laboratory Science.” In particular, they offered the example of how the light sensor then available from the American Printing House for the Blind and originally developed at the Lawrence Hall of Science at the University of California, Berkeley, could be used in elementary science classes to detect the relative amounts of visible pollutants in four jars of water samples of different pollutant levels. The light sensor, when held against the exterior of each glass jar, produced varying tones depending on the light intensity due to higher or lower levels of pollutants found in each water sample. This paper also implied that the light sensor could be used in a wide variety of other elementary science activities but did not give specifics as to these other possible applications.

Hadary and Hadary Cohen’s Laboratory Science and Art for Blind, Deaf, and Emotionally Disturbed Children (1978), described numerous techniques to teach scientific concepts to young children by means of simple experiments and art representations. They cited the importance of the use of tactile art in the teaching of scientific concepts by having the students create models as illustrations. Numerous concepts were covered, including electric circuits, plant biology, greenhouses, pulleys, magnetism, liquids and solutions, solids/liquids/gases, mass, density, light, sound, and many more. This was primarily a handbook of experiments and explorations that teachers could use to instruct blind, deaf, and emotionally disturbed students, and provided detailed materials lists and instructions for all of these activities. The authors also included general suggestions for teaching such students.
In “Common Sense and Sensitivity in Teaching the Blind,” Gough (1978) pointed out that blind students’ need for independence is important and encouraged educators to adapt experimental procedures to allow students to observe phenomena non-visually. The article included a word of caution both for educators and blind students regarding the design of these adaptations: “[T]he easiest error for a teacher to make is to assume that the visually impaired student ‘sees’ the same things with his fingers as one sees with one’s eyes” (p. 34). Gough described the importance of students with BLV learning to light Bunsen burners and handle sharp tools such as syringes and knives in the biology laboratory, and briefly mentioned the importance of the use of tactile models in biology classes.

Gough mentioned that most Braille books of the time did not contain illustrations of figures in a raised-line format, and that students with BLV would probably not know what a common, but unfamiliar, object was if it was handed to them since they had never ‘seen’ the object before in illustrations. Simple adaptations could be made to laboratory procedures so that students with BLV could utilize their other senses to participate. He also stated that non-visually-impaired students could likewise use tactile representations as an aid in their own learning.

Additionally, Gough discussed other simple ways to encourage blind students’ independence in classrooms and laboratories, such as educators having the students with BLV make Braille labels to be applied on equipment, as well as putting Braille labels on homework and tests to provide access to grade information.

In 1979 the Macrolab, an interdisciplinary center for science students with disabilities, was established at the New Jersey Institute of Technology, as described in
The Macrolab: A Center for the Handicapped at NJIT (Cochin and Herman, 1981) and “Hearing is Believing: The Modified Spectroscope” (Hinchliffe and Skawinski 1983). Participants in this program took an active part in the development of skills, methods, and devices that enabled them to overcome the barriers arising from their visual impairments. The Macrolab program produced a number of adaptive laboratory devices for college students, which provided various tactile and auditory inputs for users. Length was measured by means of a Braille ruler and micrometer. Several instruments were used to measure time, including a stopwatch, an electric timer with raised dots, and a talking clock. A talking analytical balance was used for measuring mass. Instruments for making electrical and temperature measurements included a voltmeter, ammeter, ohm meter, Wheatstone bridge, impedance bridge, and thermometer. These devices were equipped with speech output capability and combined tactile scales with audio output.

Many other readout devices at Macrolab used audio indicators, such as a color-determining device consisting of a monochromator with Braille dials connected to a light-to-sound transducer. Another audio device was a light probe that emitted an audio frequency as a function of the detected light intensity. One example of an application of this light probe was the liquid-level detector, which used a photo-detector to locate the meniscus of a liquid in a graduated cylinder or other transparent container. The detector was mounted on a long vertical micrometer screw fitted with a scale calibrated in Braille. This arrangement allowed the vertical position of the detector to be accurately read, and the variable audio frequency output notified users with BLV when the surface boundary was crossed.
A particularly innovative instrument developed at Macrolab was the modified spectroscope with a tactile scale and audio frequency output, which made it possible for blind students to study the wavelengths of light emitted by experimental samples of substances. Hinchliffe and Skawinski (1983) stated that this device was capable of straightforward qualitative measurements and complex analyses, and was simple enough to be constructed by high school science teachers.

While many of the tools and devices developed through the Macrolab project were interesting and potentially helpful, waiting until students with BLV enter high school or college before providing them with accessible tools to allow them to participate in science laboratories is, unfortunately, in most cases too late. Also unfortunately, the Macrolab tools were never commercialized and thus were unavailable to benefit students at other institutions.

Salt, Lunney, and Hartness (1980), in “General Purpose Talking Laboratory Instrument for the Visually Handicapped,” reported that laboratory microcomputers were quickly finding their place in curricula at all levels and in all fields of study. Technology developments had made computers accessible to persons with visual impairments. Computer programmers with BLV were being trained and employed as a result of the microcomputer. The advent of the computer also allowed for the development of input/output modules that included Braille terminals and voice synthesizers. The control of laboratory instrumentation by microprocessors and microcomputers was evolving to become a routine practice. Salt et al. stated that as microcomputers became more common in the classroom and in the laboratory, and as microcomputer technology became accessible to people with visual impairments, it was certain that microcomputers
would become increasingly important as laboratory tools for students who were visually impaired.

DeLucchi and coworkers at the Lawrence Hall of Science developed the Science Activities for the Visually Impaired/Science Enrichment for Learners with Physical Handicaps (SAVI/SELPH) curriculum for students at the California School for the Blind, as described by DeLucchi and Malone (1982) in “SAVI (Science Activities for the Visually Impaired).” The primary goal of the SAVI/SELPH project was the production of science activities to give children with BLV, aged 9 to 13 years, structured experiences with real objects and organisms. It was determined that the most effective way for children to learn, particularly students with BLV, was with hands-on activities designed to encourage the students to exercise all available senses. Basic plastic cups and balances, notched syringes, and Braille-labeled float devices for graduated cylinders were employed. The SAVI/SELPH curriculum sought to enhance the scientific literacy, logical thinking abilities, and manipulative skills of children with BLV through hands-on activities.

*Handbook for Itinerant and Resource Teachers of Blind and Visually Impaired Students* by Willoughby and Duffy (1989) included a chapter on teaching science. The authors discussed a series of suggestions found through personal experience to be beneficial in teaching various science concepts. They discussed the use of a lab partner to provide descriptions of the visual aspects of science laboratories and experiments. They outlined a method of working with a lab partner on the use of a microscope, in which the blind student learned to manipulate the knobs on the instrument while a sighted student provided verbal descriptions of the slide being viewed. The importance of Braille
labeling whenever possible was also discussed, and the use of tactile drawings and models was emphasized as being helpful both in the laboratory and in general science classes. Skeletons or models with removable layers were found to be helpful in the instruction of human anatomy. The use of beans glued onto a piece of paper to make outlines of scientific concepts in biology classes was also suggested.

Willoughby and Duffy emphasized the importance of blind students reading the assigned textbook materials prior to lecture to provide them with a solid foundation of the concepts to be presented. A testimonial regarding the difficulties of studying electrical engineering in the 1960s was also included, and described the perseverance and creativity that two blind students had needed to succeed in this technical area of study. The efforts of these two successful students led to many blind persons later succeeding in engineering fields. The authors also suggested that if advanced study was being pursued by persons with blindness, advanced technological solutions would be needed to allow them to continue beyond introductory levels in science classes.

In the *Teacher’s Manual for Adapting Science Experiments for Blind and Visually Impaired Students* by Dion et al. (2000), the authors discussed a number of adaptations to science curricula for blind and low-vision students. This work was conducted in the United States and Denmark, and mainly covered physics and chemistry. The manual outlined a number of low-tech tools as well as minimal laboratory procedural modifications and a few advanced modifications. The authors stated early in this text that allowing blind and low-vision students to carry out laboratory experiments without any adaptations would not foster much, if any, learning. This statement was based on the fact that if there were no audible or tactile way for a BLV student to be informed of a
chemical change occurring during a chemistry experiment, or a physical change occurring as part of a physics experiment, the student would have no means of ascertaining this change. Further, the authors commented on how BLV students’ perceptions of their physical surroundings are very different from those of their sighted counterparts, because BLV students are often unaware of various aspects of their environment if they do not come into physical contact with these aspects or are not told of them.

Dion et al. described several physics and chemistry experiments involving pendulums, oxygen and carbon dioxide detection, and circuit kits providing tactile experiences for circuitry concepts. The authors also felt that any experiment could be adapted for blind or low-vision students by means of a sighted laboratory assistant. This assistant could read visual displays on laboratory meters, but when there were ways for the BLV students to manipulate the meters to get a tactile or auditory readout on their own, this latter approach was encouraged. The authors also indicated that much practice with the various techniques was necessary before full competency with the laboratory apparatus was possible.

Dion et al. also described in detail some basic aspects of teaching science to students with low vision. The use of contrast, large print, and reduction of glare to assist such students in their perceptions of objects in the laboratory was outlined. The authors also recommended an increase in the size of objects to further help the visualization of aspects of experiments when possible. Increased or decreased light and the use of colors to aid in perception were mentioned, and students with dilated pupils were discussed as being adversely affected by excess light and glare.
The authors listed 30 questions for educators to ask themselves when determining whether laboratory equipment adaptations were appropriate for their visually impaired students. Among other issues, the questions addressed visual, tactile, auditory, and instructional aspects of the equipment and any related text; the ease with which laboratory objects could be handled; and the facility with which students with BLV could deal with power-supply issues such as changing batteries and using the sockets and power cords. Dion et al. stressed that a minimal level of laboratory procedure adaptations were necessary to give BLV students the ability to perform the same laboratory experiments as their sighted counterparts. These minimal lab procedure modifications were also encouraged to save teachers’ time in planning.

The authors also discussed how glassware usage should be managed, and recommended that clamps and ring stands be utilized extensively to prevent possible spills or breakage of glassware. Various other tools were additionally described in Dion et al., such as spring balances and conductivity probes with audible output to determine liquid levels in beakers and flasks. A lengthy resource list was included at the end of the text for readers to consult to learn more about teaching science to blind and low-vision students, along with related topics and issues.

Kumar, Ramasamy, and Stefanich (2001) discussed teaching children with “exceptionalities,” or special needs, in the science classroom, in “Science for Students with Visual Impairments: Teaching Suggestions and Policy Implications for Secondary Educators.” A number of techniques published in other papers were described; for example, a low-tech way of using a transparency system to reproduce a meter stick and using a staple gun to make raised lines to serve as tactile indicators. The authors felt such
Techniques were important for measurement because they could be transferred to skills in everyday life. The use of computer interfaces in the science laboratory was also described, based on work done by Lunney et al. (1996). The importance of raised-line drawings and how they could assist in conveying scientific concepts was also discussed. Techniques regarding taking notes by means of a tape recorder and a careful review of safety aspects in the laboratory were also included. The use of volunteers to assist in laboratory orientation was mentioned. These suggestions and others described in this paper can easily be used by science teachers for their students with BLV.

**Teaching Chemistry to BLV Students**

This section summarizes various published works describing teaching adaptations developed by educators for use in their chemistry curricula. These methods range from a low-tech tactile periodic table to the high-tech use of computer interfaces in collecting laboratory data. These published suggestions serve as a good starting point for anyone who wishes to teach a student who is blind or visually impaired in the chemistry classroom. It is also possible some of these techniques have direct applications in other science classrooms as well.

In a very early work titled “Notes on Elementary Science,” Evans (1927) discussed specific adaptations for teaching chemistry to students with BLV, and offered a list of 10 adapted lessons to convey various fundamental concepts. Activities included learning the states of matter by melting wax or turning water into steam, learning about solutions and evaporation by dissolving salt into water and then evaporating the water to produce salt crystals, and learning about combustion and fire with the use of a Bunsen
burner and exploring the resulting fumes, scorched rags, and soot. Some of the lessons involved little or no adaptation for students with blindness because doing so was unnecessary, while others incorporated simple and inexpensive adaptations in technique, such as allowing students to thoroughly feel all pertinent equipment prior to the beginning of the experiments.

Bryan (1952) in “Chemistry for the Blind” claimed that students with BLV could benefit from lectures and teacher demonstrations in chemistry classes. This could be achieved, he said, through tactile, auditory, and olfactory observation of experiments. He further suggested ways for high school students with blindness to make their own observations about chemical phenomena. Some suggested activities involved tactile explorations of laboratory equipment, instruments, and materials; tactile explorations of metals, minerals, and crystals; identifying various elements through senses other than sight; identifying airborne substances and petroleum products through scent; and comparing the weights of different liquids of equal volume. Bryan did not discuss either specialized laboratory apparatus or quantitative chemistry experiments, but rather simply indicated that these might be adaptable. However, while suggestions like Bryan’s are useful and employed by students with BLV in chemistry classes today, they are rudimentary and inadequate in themselves to allow BLV students to fully participate in chemistry learning.

Wexler’s Experimental Science for the Blind: An Instruction Manual (1961) included a list of 18 quantitative and qualitative chemistry experiments that students with blindness had successfully performed by means of specialized laboratory equipment. Rubber balloons were used to collect gaseous reaction products. Color changes and the
ignition and extinction of flames were detected using either a light-intensity indicator or a combination photocell and buzzer. A sensitive spring balance that was readable to 0.01 g was used to detect mass changes. Students with blindness performed experiments on combustion, precipitation, catalysis, the electrolysis of sodium chloride, and the titration of acids and alkalis, etc.

Hiemenz and Pfeiffer (1972) published a chemistry experiment for college students with BLV, as reported in “A General Chemistry Experiment for the Blind.” The objective of this experiment was to determine the weight of trichloroacetic acid through a conductometric titration of the acid with a sodium hydroxide solution, and to locate the end point using audible tones. A modified triple-beam balance was used for weighing. The authors reported that the student with BLV made all measurements without assistance and was able to record data with a Perkins Braille Writer, but needed some assistance with laboratory manipulations.

Struve et al. (1975) discussed their study of an educational intervention for students with visual impairments called the Science Curriculum Improvement Study (SCIS), in “The Effect of an Experiential Science Curriculum for the Visually Impaired on Course Objectives and Manipulative Skills.” Two units of this curriculum, “Interaction and Systems” and “Subsystems and Variables,” were examined with a particular emphasis on chemistry-related manipulative skills such as pouring and filtering liquids and organizing objects. The units involved a series of ungraded activities designed to assist students having BLV with basic science concepts. Struve et al.’s study included a control group and an experimental group, with the experimental group being provided with the SCIS curriculum consisting of one-hour sessions once per week for 13 weeks.
While the study found little improvement in scores between the pre- and post-tests of the control group, the students in the experimental group demonstrated a substantial increase in their post-test scores. This work illustrated how students with visual impairments could benefit from supplemental instructional materials that went beyond the standard science course curriculum.

In “A pH Titration Apparatus for the Blind Student,” Tallman (1978) described an accessible setup that attempted to provide students with a feel for the changes in solution composition that accompanied the addition of titrant in a neutralization titration. The signal output from a pH meter was conditioned and detected by an audio-encoded Simpson multimeter. The Simpson multimeter was a standard device modified by replacing its meter movement with a potentiometer. The potentiometer had a tactile dial and was nulled aurally. The scale was calibrated by the multimeter to correspond to a pH range of 2 to 12. A 10 mL Metrohm piston buret with a Braille-labeled scale was used to dispense the titrant. A Perkins Braille Writer was used by the blind student to record the data. The setup allowed the blind student to perform most required laboratory operations, including pH calibration of the Simpson multimeter. The student was able to collect and record the titration data, and correctly identified an unknown. The student’s estimates of its formula weight and its three pK\textsubscript{a}’s (the negative logarithm of the acid ionization constant) compared favorably with values in the literature. As far as could be determined from the literature, this technology was used in this one instance only and was never tested with other students or under other circumstances, i.e., at other schools.

In “Chemistry and the Visually Handicapped,” Crosby (1981) discussed a number of practical techniques for instructors of chemistry to teach students with blindness and
visual impairments. Suggestions included allowing a student with low vision to sit near extra lighting and having the instructor read aloud everything he or she writes on the chalk board. The use of specific language was important, Crosby (p. 206) said: “Be explicit. The phrase: ‘When the temperature increases from 20 to 50° C’ is far more meaningful than ‘When the temperature goes from here to there.’” Such specificity adds meaning not only for students with BLV but for their sighted counterparts as well.

Crosby also encouraged instructors to keep things simple and not let the planning process for teaching a student with BLV become overwhelming. Crosby pointed out that most accommodations should be negotiated directly with the student having BLV based on that student’s individual needs. For students with total blindness, working with a partner in the laboratory was discussed, preferably another student who had already taken the class and was willing to volunteer his or her skills. The student with blindness should instruct the assistant on what to do in the experiment; the role of the partner was auxiliary only. Crosby also pointed out that time constraints could be dealt with by simply scheduling the student with BLV for two back-to-back lab sessions.

Working with the lab safety officer regarding any concerns was necessary, as it was for all students, said Crosby, but additional safety protocols for students with BLV were generally limited to simple strategies such as not seating these students in high-traffic areas and letting them explore the locations of the exits, fire extinguishers, and emergency showers before the first class session. The use of guide dogs in the laboratory was not recommended. Crosby said these animals should be placed in an area outside the laboratory to minimize possible injury by chemical spills or broken glass.
While Crosby’s ideas were progressive for their time, the recommended use of a lab assistant for students with blindness would have denied them a hands-on laboratory experience. Crosby said the use of this method by a student with BLV was analogous to professional chemists directing others such as graduate students or technicians to perform their experiments. This analogy, however, may not be appropriate, because professional chemists receive a great deal of hands-on experience while in training, but students having BLV who are paired with a sighted lab assistant would receive little or none.

Lunney and Morrison’s “High Technology Laboratory Aids for Visually Handicapped Chemistry Students” (1981) reviewed a number of commercially available high-tech devices for the visually impaired and described efforts to develop a general-purpose laboratory microcomputer system called the Universal Laboratory Training and Research Aid (ULTRA) for people interested in scientific and technical careers. This was a cutting-edge approach for its time. The authors noted there were few aids available to allow the visually impaired to make accurate laboratory measurements and to interact independently with the instruments. Their list of commercial aids included talking instruments such as micrometers, depth gauges, multimeters, pH meters, and computer terminals.

The ULTRA was designed to serve as both an educational tool for college students and a research tool for professionals. It could function as a talking data acquisition and data analysis system, talking terminal, stand-alone talking computer, and stand-alone talking calculator (Lunney and Morrison, 1981; Morrison et al., 1981). The system could be connected to many instruments with either an analog or digital output signal. Software for the system could assist students in performing experiments regarding
pH measurements, visible spectrophotometry, infrared spectrophotometry, titration, and gas chromatography (Lunney and Morrison, 1981; Cetera et al., 1981). Although this device was multifunctional and useful in the research chemistry laboratory environment, and thus carried over to classroom applications, it was limited in its practicality as a result of the high cost associated with the technology. Although the authors expected commercialization of the ULTRA interface, this never came to fruition and thus ULTRA did not become available to the general public. Also, these devices, as far as published literature indicates, were never tested with other blind chemists in documented situations.

Smith (1981), in “Teaching Aids for Visually Handicapped Students in Introductory Chemistry Courses,” discussed the major aspects of a general chemistry curriculum covering the periodic table, stoichiometry, and bonding. The author described various ways to make a tactile periodic table that was lightweight and compact for blind students to use. Smith also discussed how magnets that are Braille labeled could be used to assist with Lewis dot structures as well as chemical bonding and stoichiometry. These and other tips presented in this work were low-cost techniques to assist chemistry teachers in providing accessible materials for their blind students in critical subject areas of chemistry.

Swanson and Steere (1981) discussed laboratory safety concerns in “Safety Considerations for Physically Handicapped Individuals in the Chemistry Laboratory.” Using data both from governmental and corporate publications, they were able to determine the safety track records for employees with disabilities versus their nondisabled counterparts, and found that workers with disabilities – including those employed in laboratory settings – presented no greater safety risks than did their
colleagues who were not disabled. They suggested that the situation was likely no different for students with disabilities as compared to students without disabilities. Also, they noted that insurance premiums paid by these employers were no greater as a result of hiring persons with disabilities.

Swanson and Steere discussed key points that people with visual impairments should keep in mind when working in the laboratory. The importance of being organized and familiar with all equipment to be used in an experiment, and having it within reach, greatly aids in a BLV person’s ability to safely perform an experiment. Also, with regard to students with BLV participating in classroom laboratory settings, the importance of working with the course instructors on proactively addressing any safety risks was stressed. The authors pointed out that having discussions with the school’s safety officers was important; however, it was likely these safety officers would not be knowledgeable about the specific needs of persons with disabilities. Additionally, they said, the needs of each person with a disability regarding laboratory activities are individualized, and thus each such person should be thoroughly consulted. The authors recommended that pathways to emergency exits be kept clear and a safety “buddy system” be implemented. Rapid exits should be practiced in drills to ensure safe egress in case of laboratory emergency. If these precautions were followed, along with adhering to the various legal obligations pertaining to equitable treatment of persons with disabilities, people with visual impairments could have successful laboratory experiences at no higher safety risk than that of their sighted counterparts, asserted the authors.

Anderson (1982) described the importance of appropriate instrumentation in the chemistry laboratory for students with BLV, in “Chemical Instrumentation for the
Visually Handicapped.” He discussed how the Optacon, a device that utilized a small handheld camera to take images of printed characters and produced vibrational outlines of those characters on a separate pin touch pad, could be utilized to read display screens on laboratory equipment such as various amplifiers and, particularly, digital multimeters. The author also addressed safety concerns in the laboratory, and how the laboratory could be hazardous for persons with BLV as well as their sighted counterparts. This interface of the Optacon along with standard laboratory equipment provided great versatility of use for students with visual impairments. However, the author failed to mention that this approach was limited by the fact that the Optacon was priced at over $10,000. Optacons have not been manufactured since the early 1990s, so this type of interface is no longer available anyway. However, the Optacon digital multimeter interface was a valuable laboratory tool for students with BLV who had access to it.

Horowitz et al. (1987), in a study titled *Adaptation of the Chemistry Laboratory Curriculum for Visually Handicapped Students*, evaluated the feasibility of blind students’ participation in a general chemistry laboratory course. They looked at a number of experiments and developed a few audible tools, and concluded that, from the perspective of 1980s technology, BLV students would always require some level of sighted assistance in carrying out experiments. Their work was outlined in a National Science Foundation (NSF) Final Report, but the only published discussion of their efforts and results appeared in Seltzer’s (1986) “Chemistry Lab Adapted for Blind Students.”

In “When Versa…Goes Apple…for a Blind Chemist!,” Cartier and Jones (1988) described how a device known as the VersaBraille, which offered a refreshable Braille display, could be interfaced with a 1980s Apple II+ desktop computer. (A refreshable
Braille display consists of a series of pin matrices in the eight-dot Braille configuration. Refreshable Braille displays utilize piezo technology to raise or lower the pins in the desired dot patterns as determined by the software of the device.) This hardware interface gave blind students the ability to access databases of information to assist them with their data collection and comparison activities. The authors stressed the important role that a microcomputer could play in a blind person becoming a professional chemist or other scientist.

Flair and Setzer’s “An Olfactory Indicator for Acid-Base Titrations” (1990) discussed the creation of an olfactory acid/base indicator to assist students in a multisensory learning experience. Specifically, they used eugenol as the acid/base indicator. This indicator was compared to phenolphthalein and thiophenol. The eugenol was found to be accurate. This type of olfactory response can assist persons with blindness and visual impairments as well as other special-needs learners requiring a multisensory approach, but has limitations. Although this work was found to be beneficial to the subjects in question, olfactory detection can vary from person to person, based on the general health of each person at the time of the test. Also, with extended exposure to odors, olfactory sensitivity can degrade over the period of a laboratory session, thus making it difficult to reproduce the same measurement consistently.

Lunney (1994), in “Development of a Data Acquisition and Data Analysis System for Visually Impaired Chemistry Students,” discussed the construction of the personal science laboratory (PSL) for blind and visually impaired students. This computerized arrangement allowed for the interface of laboratory probes through a serial port and text-to-speech output, and was used in conjunction with a talking voltmeter. The PSL was
tested with a general chemistry course curriculum and allowed blind students to conduct a large percentage of the laboratory activities without a sighted assistant. It was the expectation that the PSL would become commercially available. As far as we know, this did not come to pass.

Lunney et al. (1996) successfully interfaced a Braille ‘n Speak note-taking device, produced by Blazie Engineering (which was later purchased by Freedom Scientific), with commonly available laboratory equipment including balances, pH meters, an ultraviolet-visible spectrometer, and a spectrophotometer, as reported in “Science Education for Students with Disabilities.” The Braille ‘n Speak, in its “speech box” mode, can read ASCII input from lab devices through RS-232 connections. This interface was one of the first initiatives for accessible research-grade laboratory equipment, and could be used by students with blindness in science classes at the high school and university levels.

In “Chemistry for the Visually Impaired,” Ratliff (1997) indicated that only a small number of laboratory modifications were necessary to make participation easier in a general chemistry laboratory for students with BLV, and that these accommodations were relatively low cost. The major difficulty identified was the lack of a Braille textbook. Not having the concepts in Braille made it difficult for the students to track their data. This paper also described several demonstrations utilizing a buzzer connected to the LED display of a conductivity probe, which allowed students with BLV to respond along with their sighted counterparts.

Gupta and Singh (1998) reported in “Low-Cost Science Teaching Equipment for Visually Impaired Children” that they were able to use inexpensive electronic equipment to build different types of detectors. Examples included a null detector with audio output,
a probe connected to an electronic thermometer, and a colorimeter with an embossed dial. All of these devices could be made from locally available materials. The authors felt that the elimination of speech output devices and the Optacon was possible using tactile representations.

Milchus and Goldthwaite (2000) researched laboratory tools for students with BLV, and developed speech-accessible sensors and probes using the Vernier Logger Pro software and Lab Pro hardware, as reported in “Using Computers to Make Science Labs Accessible to Students with Disabilities.” These probes included a pH meter, thermometer probe, conductivity detector, and many others. Milchus and Goldthwaite employed a JAWS scripter to write scripts allowing the JAWS text-to-speech screen reader to speak data values as they were collected. Although these scripts proved to be useful at the time, they were not updated as new versions of Logger Pro and JAWS became available.

*Teaching Chemistry to Students with Disabilities: A Manual for High Schools, Colleges, and Graduate Programs*, edited by Miner et al. (2001), discussed a number of techniques for teaching persons with disabilities in high school and college chemistry classes. The book’s contributors found that many of the suggestions for laboratory participation would also work in other sciences. Tips on assessment related to test taking and lab report writing were also suggested. For example, students with low vision could simply be given large-print exams and textbooks. Persons with blindness could work with a reader – a person assigned to read printed text materials and, in many cases, record them in audio format for later reference.
Miner et al. (p. 62) described the directed laboratory assistant approach to working in the chemistry laboratory, in which a qualified person is assigned to work with the student who is blind to perform the physical manipulations in the lab that the student with BLV is not able to perform. This assistant also provides information about visuals such as descriptions of solution color changes during experiments. Aspects of universal design in the chemistry laboratory were also presented in Miner et al., as well as an extensive section on federal legislation related to the education of persons with disabilities. A discussion of access technologies and a lengthy resource list of organizations serving persons with disabilities were additionally included.

Pence et al. (2003), in “Effective Laboratory Experiences for Students with Disabilities: The Role of a Student Laboratory Assistant,” described a dual-case study investigating the usefulness of a sighted laboratory assistant. In this work, the same sighted assistant was paired with two different students having varying disabilities. The first was in a wheelchair; the second was visually impaired. These students were enrolled in classes during successive semesters. The student with the visual impairment was partnered with another student in the class along with the laboratory assistant. The student with BLV was required to instruct the laboratory assistant as to what to do in the lab, and the assistant was to do only what the student could not carry out independently. The laboratory assistant was to intervene only if an instruction compromised the safety of anyone in the laboratory, and was required to explain the refusal to carry out the task. The teacher was to direct communications to the student instead of to the assistant. Once rapport between the laboratory assistant, the student with BLV, and the student’s lab
partner had been established, the group worked well as a team, and a positive experience was had by all involved.

Pence et al. included a list of 10 recommendations for working with students with disabilities in laboratory classrooms. These suggestions included advance notification being provided to pertinent faculty members regarding the enrollment of a student with disabilities in a laboratory class; faculty members researching possible adaptations and consulting with the student on required accommodations; advance preparation by the student prior to each experiment to enhance the student’s lab experience; careful selection of a laboratory assistant; an in-depth review of safety needs and emergency procedures, with input from the student regarding the types of safety assistance required; and strict limitations on what the laboratory assistant is to do or not to do for the student.

Pence et al. recommended that instructors take the time to research the disability in question and become familiar with the school’s policies regarding the provision of accommodations to students with disabilities. They also pointed out that a substantial amount of time and diligence are needed to find a suitable laboratory assistant who incorporates competence in the laboratory, excellence at following directions, and patience. Additionally, they stated that all faculty members, instructors, and classmates interacting with the student during lab sessions should direct their interactions to the student and not to the laboratory assistant, and that the laboratory assistant should work to ensure this.

A research study by Mayo (2004) for her doctoral dissertation at Purdue University, titled *Assessment of the Impact Chemistry Text and Figures Have on Visually Impaired Students’ Learning*, investigated how BLV students process visual concepts in
chemistry ranging from simple molecular geometries to hybridization. She conducted a series of interviews with three students, one blind chemistry professor, and one sighted biochemistry professor. Each subject was asked questions regarding how they visualized various aspects in chemistry. The biochemistry professor had had a blind student at one time and commented on how this student had performed in class. Mayo sought to identify a set of standards regarding how best to illustrate visual concepts for visually impaired learners. Her results did not identify a specific set of standards, but rather indicated that each visually impaired person is an individual, and the individual’s learning style determines the best strategies for acquiring the concepts in question. Also, whether a subject had been blind since birth or possessed some vision at one time impacted Mayo’s study. She found that subjects with usable vision in the past tended to have better comprehension of visual chemistry concepts. Those who had been blind from birth tended to require more assistance with visual descriptions and to be further off base.

Mayo’s work was a valuable first step in the area of tactile graphic representations in chemistry and in how these graphics could be designed to better aid visually impaired learners. However, more work involving a larger sample group would be necessary to determine if blindness from birth versus once having possessed some usable vision really does impact a person’s ability to understand chemistry concepts. This type of study could further be expanded to include biology and other scientific disciplines.

Supalo’s “Techniques to Enhance Instructors’ Teaching Effectiveness with Chemistry Students Who Are Blind or Visually Impaired” (2005) illustrated a series of practices used during his undergraduate studies at Purdue University in the 1990s. He described how students with BLV could take notes and the techniques he used to access
overhead transparencies and other graphical concepts from lecture presentations and textbooks. These methodologies included utilizing a standard tracing wheel along with a piece of Braille paper in conjunction with a rubber mouse pad to make images on the paper. The paper was then flipped over to access the image as it was meant to be presented from left to right. The challenges associated with access to textbook materials were described, and he explained that flexibility in textbook choice could be helpful, in case the course text is not available in Braille or audio format.

Further, Supalo described the proper use of the directed laboratory assistant approach to working in the chemistry lab, along with techniques for taking quizzes and exams, and the importance of working with course instructors to determine appropriate locations and circumstances for exams. The role played by the institution’s disabled student services office regarding the education of students with BLV was discussed and explained as being a supportive or ancillary resource to provide assistance in working out course-related accommodations between instructors and students.

In “A Project to Make the Laboratory More Accessible to Students with Disabilities,” Lunsford and Bargerhuff (2006) discussed a workshop program at Wright State University called Creating Laboratory Access for Science Students (CLASS), which was developed to train science teachers on methods of adapting laboratory curricula to be more universally designed. These laboratory modifications covered biology, physics, and chemistry. Among the chemistry topics discussed were physical properties, chemical properties, the periodic table, balancing chemical reactions, acids and bases, and water monitoring. One important modification the authors proposed was the use of plasticware in place of regular glassware to prevent possible breakage. The
CLASS project actively incorporated science educators along with persons of varying disabilities in the workshops. The workshops were designed to give science teachers the opportunity to have hands-on laboratory experiences while working with persons having a range of disabilities. The workshops took one to two weeks each summer, and travel, lodging, and stipends were provided to participants. The CLASS workshops also provided mini-grants for investigators to work on universal-design projects that, in turn, led to the training of more than 700 students. It was stated by the authors that properly incorporating hands-on laboratory experiences for persons with disabilities leads to these students being three times more likely to pass standardized tests.

Neely (2007) discussed the various adaptive technology devices then on the market for students with BLV to utilize in the science classroom, in “Using Technology and Other Assistive Strategies to Aid Students with Disabilities in Performing Chemistry Lab Tasks.” Contact information and approximate cost for each device was included in this work. For students with low vision, a magnification device known as the Clarity can be used in the laboratory. A camera attached to the device captures images that are then enlarged and viewed on a screen. The device can be attached via a clamp to a benchtop to further assist in its laboratory use. Talking timers in the science classroom to assist students with low vision were also mentioned. An audible beaker with tone output to indicate to students with BLV when they are nearing the top was not found to be helpful. Other than the “talking” beaker, the devices were shown to be very useful in providing hands-on laboratory experiences.

“Making Science Fair: Making Science Instruction and Labs Accessible for Students Who Are Blind or Visually Impaired,” by Winogad and Rankel (2007), covered
a series of low-cost ways to illustrate chemistry and physics concepts for middle school and high school students with visual impairments. They discussed utilizing a set of substitute characters to represent chemical symbols in Microsoft Word files. These shortcuts included adaptations such as -> to indicate “goes to” in a chemical reaction, ^- to indicate a negative superscript, and _ to indicate a subscript. These techniques were employed to facilitate the reading of chemical equations because the JAWS screen reader does not correctly read some mathematical symbols.

Winograd and Rankel also suggested the use of Braille-labeled magnet boards to illustrate mathematical operations and algebraic manipulations with gas laws, and model kits to illustrate chemical structures and organic molecules. A few laboratory adaptations were also mentioned, such as tactiley labeling a basic spring scale or etching small notches on the sides of syringes. Additionally, they suggested utilizing an inexpensive talking thermometer. The use of laptop computers was discussed for recording data and reading electronic files regarding laboratory procedures and class assignments.

Poon and Ovadia’s “Using Tactile Learning Aids for Students with Visual Impairments in a First-Semester Organic Chemistry Course” (2008) described their experiences in teaching organic chemistry to a college student with BLV. Various methodologies were discussed, but one found to be particularly beneficial utilized an orbit molecular model kit from Indigo Instruments (based in Waterloo, Ontario). This kit provided conveniently sized pieces that were easily transportable and manipulable by the instructor and the student, and was used to augment the student’s understanding of organic chemistry concepts. The kit was also used by the student during lectures, along with models assembled by either the instructor or a teaching assistant. Additionally, two-
dimensional methods were tried, including using raised-line image enhancer technology on polymer-based paper. This technique produces tactile representations corresponding to the ink of printed materials when the polymer paper is exposed to a UV lamp; however, the authors’ attempts to place Braille labels on such paper were not successful.

“Low-Cost Laboratory Adaptations for Precollege Students Who Are Blind or Visually Impaired,” by Supalo et al. (2008), illustrated numerous low-cost methodologies to assist students with BLV in the chemistry classroom, including Braille-labeled magnets, Styrofoam balls, clay balls, straws cut to varying lengths, commercially available model kits, and more. This work discussed ways to modify periodic trends, valence shell electron-pair repulsion (VSEPR) theory, basic laboratory methodologies for measuring volume, and the use of a two-dimensional felt board to illustrate organic chemistry mechanisms. The Submersible Audible Light Sensor (SALS) developed in the Chemistry Department at Pennsylvania State University was described, and how it could be used to indicate color changes to persons with blindness. Additionally, the paper included an overview of the uses of technology in the chemistry classroom as pertaining to learners with BLV.

A subsequent paper by Supalo et al. (2009b), “Using Adaptive Tools and Techniques to Teach a Class of Students Who Are Blind or Low-Vision,” offered information about the summer 2007 National Federation of the Blind’s Youth Slam event hosted at Johns Hopkins University in Baltimore, Maryland. This work illustrated technologies and techniques that could be implemented when teaching an entire class of students with BLV. Several ILAB tools were prominently featured in the chemistry segment of this event, demonstrating that these tools are appropriate for teaching students
with BLV. Other science segments at the event included biology, air science, engineering, and physics. Some of the SAVI/SELPH tools were also used, such as notched syringes. Cafeteria trays were utilized as workspaces for students conducting experiments, minimizing spills both on the benchtop and on expensive computer equipment. Supalo also described the laboratory procedures used in the chemistry experiments. The 2007 Youth Slam activities serve as illustrative examples of how ILAB tools can be successfully incorporated into chemistry curricula in the laboratory.

**Teaching Biology to BLV Students**

The following literature describes various techniques that have been used to teach biological concepts to students who are blind or low vision. Many of these methodologies assumed the availability of a Braille textbook. They also utilized models of cells, plants, and animals, and raised-line drawings produced through various means. In certain instances, the existence of residual vision was shown to greatly complement the learning experiences of BLV students in the biology laboratory.

Dawson, in “Biology for the Blind” (1958), described methods he used to teach general biology to college students with visual impairments. He emphasized two techniques: careful verbal descriptions of lecture materials and the use of models. Although standard commercial models helped demonstrate the relative positions of major organs within the human body, their overall usefulness to students with blindness was limited due to inadequate tactile distinctions. Commercially available models were intended for sighted students, and many physical details were distinguished by color. As an alternative, sighted students prepared clay models of organs for their classmates with
visual impairments. These models were designed to fulfill the expressed needs of the users with visual impairments and proved to be much more beneficial than the commercial versions. One major limitation of this method, however, is that clay models are not very transferable from school year to school year as a result of distortions due to handling and a lack of design for long-term use, since the models were made by students and not by professional artists.

“What About Your Visually Defective Students?” by Bunner and Bunner (1968) presented practical suggestions for teaching biology to visually impaired students enrolled in mainstream schools. The authors gave examples of typical class activities in which these students could participate, and stressed that blind students generally need not be exempted from activities required of the class as a whole. The BLV students usually possessed the skills necessary for taking notes, preparing assignments, and taking tests. Visually impaired students in this setting were successful in performing laboratory experiments involving the dissection of plants and animals, and tactile examinations of models, specimens, and relief diagrams. In many instances, the BLV students were encouraged to touch plant and animal specimens, which provided them with a hands-on science experience. A variety of laboratory instruments were also utilized, including microscopes (which could be used by some students with low vision). For activities that required at least some residual vision, totally blind students participated by serving as data recorders for their sighted counterparts.

Cravats (1972) suggested simple non-visual observation methods for students with visual impairments to study the human digestive tract, in his article “Biology for the Blind.” Examples included chewing a banana slowly and observing the change in taste.
from bitter to sweet, digesting hard-cooked egg white in a test tube while feeling the change in texture as digestion proceeds, and examining the stomachs of various animals by touch and smell. The use of taste to learn about digestion represented one of the earliest multisensory teaching approaches and was very innovative for its time.

Tombaugh’s book, *Biology for the Blind* (1973), reported on laboratory techniques in biology for high school students with BLV, and stressed the use of basic equipment such as meter sticks and balances that had been modified to be read tactilely. She also encouraged the use of commercially available plastic graduated cylinders and beakers with ridges and grooves that could be felt. Note-taking devices like the Braille slate and stylus and a tape recorder were also found to be useful, and an improvised graphing method utilizing wire mesh was helpful in illustrating visual concepts. Additionally, the students observed all types of living plant and animal specimens by touch and dissected large frogs. As likewise noted in Bunner and Bunner (1968), when a particular laboratory exercise required sight, the students with blindness had to rely on observations made by sighted classmates. A good number of the techniques discussed in Tombaugh’s work were later found to be useful in other science classes such as chemistry and physics, and are widely utilized today by students with BLV.

Ricker (1980) published a manual for teaching introductory biology to college students with visual impairments, titled *Resource Manual: Teaching Biology to Visually Handicapped Students*. Among the main goals was to identify the variables that influenced learning at this level, such as residual vision, if any; capacity for visual memory; skill in understanding information through tactile means; capacity for independence in the college environment; and cognitive ability.
Some of the other goals toward which Ricker was working included accessibility to regular biology courses by students with impaired vision, laboratory activities that fostered students’ active participation and their progress toward becoming active learners while being less dependent on sighted laboratory assistants, and approaches to the laboratory that would allow blind students to gather information using their primary senses and abilities. By working to attain these goals, Ricker hoped to provide equal opportunities in biology courses for students with visual impairments.

Laboratory techniques investigated by Ricker included alternative microscopic viewing for students with low vision, and the use and production of three-dimensional models and tactile diagrams. Ricker asserted that models and tactile diagrams were essential tools for teaching biology to visually impaired students, and explained why verbal descriptions were often not sufficient equivalents. He discussed several methods to produce tactile diagrams and evaluated each on the aspects of production expense, product durability, and ease of reproduction.

To help visually impaired students become active laboratory participants, Ricker also investigated measuring techniques to allow these students to collect their own data regarding liquid volumes, mass, and temperature. He suggested that students measure liquids with modified syringes, squeeze-type dispensers, pipettes, Repipet Jr. dispensers, and the Audicator, a sensor that emitted a high-pitched sound when immersed in ionic solutions. Mass could be measured on a commercially available triple-beam balance with a light sensor attached to help students detect pointer movement and determine when the beam was in balance. Temperature measurements could be made with a talking thermometer. Ricker pointed out that students with visual impairments generally needed
more time than did sighted peers to complete laboratory activities. He also recommended using basic laboratory safety equipment, such as aprons, goggles, sleeve protectors, disposable plastic gloves, and reagent containers with tactile labels and spill-proof openings.

Ricker found that the use of residual vision greatly enhanced students’ learning experiences for those who possessed some vision, but the use of models and raised-line tactile graphics allowed involvement by totally blind students. He also found that simply describing the appearance of slides and other specimens was not sufficient to provide an equal learning experience. This finding is particularly supportive of the assertion that hands-on techniques, both those of Ricker and others, can successfully be utilized in teaching sciences to BLV students.

In “Teaching Biology to the Visually Impaired: Accommodating Students’ Special Needs,” Womble and Walker (2001) discussed the techniques they developed to teach a university student with blindness in two biology classes. Perhaps most significantly, they utilized a spirometer interfaced with a computer to measure the flow of air and other gases from human lungs. Simply reading the numbers on a computer screen was not found to be sufficient to provide the student with a tactile feedback representation of the volume transferred. Therefore, they attached a balloon to the output valve of the spirometer to allow it to fill with the gases and thus created a tactile representation of the gas output. The size of the balloon was then measured and volume was calculated.

To illustrate other concepts, Womble and Walker encouraged the student with blindness to use his own pulse to get a sense of heartbeat. A stethoscope was applied to
allow the student to listen to his own pressure changes in blood flow caused by a blood pressure cuff; narration was provided in reading the gauge data values to the student. The instructors also provided individualized instruction on the concepts covered in laboratory classes. These tutorial sessions were supplemental to the student’s limited participation during labs.

Womble and Walker provided oral questions for the student with blindness to answer in place of the practicum questions given to the rest of the class; they both felt these oral questions were comparable to those of the practicums. They also illustrated numerous other simple and creative ways that biology classes could be easily modified to create more interaction between a student with BLV and the biology course curriculum.

Ely et al. (2006) reported on a pair of studies to determine how expanded audio descriptions could influence students’ learning of visual concepts during multimedia presentations, in “Increased Content Knowledge of Students with Visual Impairments As a Result of Extended Descriptions.” The authors cited as partial background a work by Vivian (1992), in which it was stated that approximately 93% of persons with blindness and visual impairments do not feel they receive full access to information presented in television and film productions.

Ely et al.’s project, conducted through the WGBH National Center for Accessible Media (NCAM) in Boston, Massachusetts, incorporated the insertion of extended audio narration of visuals in multimedia presentations between the existing audio elements. Study One involved eight children with visual impairments (four boys and four girls), aged 9 to 11 years. Each student first took a pre-test on covered topics, and then experienced a series of educational videos primarily on physiology concepts such as the
respiratory and circulatory systems. The videos incorporated variations in the length and placement of the audio descriptions and vocal quality. Afterward, the students each took a post-test to determine how much learning had occurred. Study Two involved seven children (three boys and four girls), aged 8 to 11 years, who experienced videos covering the pulmonary circulatory system, heart structures, blood, and digestion, and likewise participated in pre-testing and post-testing. It was found that the children learned more with the inserted audio descriptions than without.

Ely et al. also discussed the possibility that the extended audio narration could assist sighted children as well with their learning processes by calling attention to details that may not have been initially apparent to them. This potential use of extended audio narration indicates a potential universal-design application.

**Teaching Physics to BLV Students**

The following review of the literature describes documented techniques used to teach physics concepts to students who are blind or low vision. There is a fair amount of carryover from paper to paper, thus demonstrating how techniques were shared and expanded over time, even if some of the techniques were serendipitous by nature.

In “Physics for the Blind,” Bryan (1951) discussed the special methods, techniques, tactile demonstrations, and Braille-labeled models he used to teach the principles of physics to high school students with visual impairments. His course covered a wide range of topics including matter, sound, measurement, pressure, motion and energy, heat, mechanics, magnetism, electricity, and electronics. The students were allowed to investigate demonstration apparatus by touch. Bryan often used simple hands-
on classroom activities to demonstrate theoretical concepts and gave several examples, such as throwing, catching, and holding a ball to illustrate the concepts of kinetic and potential energy. Bryan showed that the absence of sound in a vacuum could be indicated in the usual way with an electric bell placed inside an evacuated bell jar, and harmonics were illustrated with the aid of stringed instruments and a tuning fork. These types of demonstrations were not much different from those performed in typical physics classes, but with the important component of active participation by the students with visual impairments. These students could catch and hold a ball, hear the presence or absence of sound, and feel the vibration of a tuning fork or string.

Ten years after the publication of Bryan’s paper, Wexler (1961) published *Experimental Science for the Blind: An Instruction Manual*, which served as an exhaustive reference to what was, at the time, the state of the art in adaptive laboratory techniques in the physical sciences. In this manual, Wexler discussed the design principles behind adaptive laboratory techniques, the preparation and use of embossed diagrams, difficulties with tactile adaptations, the coining of the term “audification of the apparatus,” and methods for performing common laboratory operations such as weighing, graphing, and measuring length. He investigated the use of probes for exploring aspects inaccessible to fingers and the applications of photoelectric cells connected to buzzers, bells, and vibrators.

He included a list of more than 200 science experiments that could be performed by students who were totally blind, including the general topics of electricity and magnetism, heat, light, mechanics, and sound. Students were to make their own observations through a combination of touch and hearing with the use of specialized
instrumentation. Wexler presented numerous photographs and schematics. The improvised equipment was much more sophisticated than most other reported adaptations up to that time. He also included a list of available electrical devices for the visually impaired.

In his master’s thesis, *Laboratory Methods in Physics for the Blind*, Henderson (1965), a student of physics who was visually impaired, described his difficulties with laboratory work as being one of two major problems a physics student with BLV had to deal with. The other major problem was keeping up with the required reading material in the scientific community. He found that one way to overcome the difficulty with laboratory work was the proper adaptation of instruments and experiments. Henderson described methods for producing raised-line drawings and tactile diagrams, and explored several aspects of the tactility of temperature, electrical sensitivity, and sense of balance as possible modes of data collection for students with visual impairments. Borrowing Wexler’s (1961) terminology, he described the “audification” of laboratory work as the most widely used method of adaptation and referred to a number of examples of its use in physics laboratories for students with visual impairments. His examples ranged from the sound of marbles dropping onto a tabletop to audio frequencies emitted by a highly versatile light probe. Henderson predicted that the digital computer would become the most useful tool in the laboratory for students with blindness.

Baughman and Zollman’s “Physics Labs for the Blind” (1977) provided descriptions of physics laboratory equipment they had adapted for use by high school students with visual impairments. They said they could not justify the purchase of specialized equipment due to the very small number of students with BLV typically
enrolled in physics laboratory classes. Rather, they developed and tested laboratory equipment meeting the following criteria: constructible from items commonly found in introductory physics laboratories, usable in multiple experiments, inexpensive to make, and quick and easy to make.

The equipment they developed included a meter stick adapted for tactile reading by the addition of dressmaker’s pins, a laboratory timer adapted with chart tape and Braille markings, plastic syringes with notched plunger stems to indicate volume, a two-pan balance adapted for tactile reading, cubes of metal and plastic of various volumes for density measurements, a graphing device made from sound-absorbing ceiling tile and golf tees, and a photocell for measuring the period and velocity of a pendulum.

Science students at the Kansas State School for the Visually Handicapped used Bachman and Zollman’s equipment to perform physics experiments. The authors determined that the equipment was effective when the students were able to use it independently; when the students could complete lab experiments in the same amount of time as their classmates; and when homework, exams, and other evaluative materials confirmed that the students were learning and retaining the physics concepts.

Weems’ paper titled “A Physical Science Course for the Visually Impaired” (1977) described a class developed for students with BLV at East Central State University in Oklahoma. The purpose of this course was to ensure that students with visual impairments had the same opportunities to experience science as did sighted students through the provision of total participation in all of the science activities. Science laboratory activities performed by students with visual impairments were similar to those required of sighted students.
Special laboratory devices were used to adapt the activities to the needs of the students with visual impairments. One way the students read instruments with digital displays was by means of the Optacon, a device that provided tactile representations of optical images. They also used a talking calculator for mathematical computations. Graphical analyses of experimental data were made with the use of a Sewell Raised-Line Drawing Kit, which offered a low-cost way of producing raised-line images on plastic film. Other laboratory adaptations included an audible light sensor and a digital universal counter that was used to measure frequency, elapsed time, time intervals, and total pulses.

Weems found that classroom instruction in operating and reading adapted instruments generally required no more than 30 minutes of additional time for students with visual impairments. The exception was teaching the use of the Optacon as a laboratory aid, which required about 10 hours of classroom instruction in advance of the physics course. The Optacon, which is no longer commercially available, required some practice for students with blindness to be able to establish a certain level of skill and efficacy in usage. The students who participated in this program typically had had no previous experience with it.

Weems concluded that the technology available at the time made it feasible for persons with visual impairments to be successful in scientific and technical careers. He stated that the goal of the program was to provide the necessary curriculum adaptations for training students with blindness to work independently in science laboratories.

Sevilla et al. (1991), in “Physics for Blind Students: A Lecture on Equilibrium,” reported on their study of basic methodologies to make physics activities regarding the concept of equilibrium more accessible to students who are blind. The technique utilized
a few low-tech laboratory tools specifically developed to teach spatial concepts in physics to blind students through tactile means. The apparatus included a balanced equilibrium device with a central arm contacting a narrow base, a device with springs to illustrate Newton’s third law (that of action and reaction), a device illustrating torques and levers, and a device illustrating the center of gravity and the effects of rotation. Students used the items while the concepts were being discussed by the instructor.

On an exam administered after the lectures, the blind students significantly outperformed their sighted counterparts: Fifty-eight percent of the students with blindness passed the exam, compared to only 40% of the sighted students. The authors concluded that the success of blind students in their study was more than comparable to that of the sighted students regarding spatial concepts.

One criticism of Sevilla’s study is that all results were given in percentages. The sample sizes of sighted versus blind students were not provided, thus it is difficult to determine how many students were impacted. The paper also did not indicate the ages or grade levels of the students involved, and did not mention plans for any follow-up studies to further test their hypotheses with physics or other science curricula.

Sahyun (2000), in *A Comparison of Auditory and Visual Graphs for Use in Physics and Mathematics*, a Ph.D. dissertation completed at Oregon State University, investigated how persons with BLV could conceptualize physics and mathematics graphs through sound. His work utilized alterations in pitch to indicate changes in the slopes of linear graphs. He also incorporated a dash tone feature to indicate negative slopes, and used continuous sounds with changing pitch to represent sine and cosine graphs. His work was tested both with sighted subjects and subjects with visual impairments. Sahyun
determined that when subjects received training on the techniques being utilized, they could successfully conceptualize approximately 70% of the information contained in the visual graphs. Sahyun concluded that this could be increased to 85% or more based on the amount of training and practice each subject received. This work later served as the basis for ViewPlus Technologies’ current product known as the Audio Graphing Calculator (AGC), now commercially available from various retailers of access products for persons with disabilities. The AGC is used by persons with BLV around the world, helping them to visualize graphics in an audible format.

Beck-Winchatz and Riccobono (2008), in “Advancing Participation of Blind Students in Science, Technology, Engineering, and Math,” discussed how some blind students, like their sighted counterparts, have an interest in astronomy that could lead to greater enthusiasm for the sciences. However, blind students have difficulty accessing the graphical materials in STEM-related courses; educators tend to lack expertise in teaching scientific concepts to BLV students; and expectations by teachers, parents, and the students themselves impact the students’ performance in science classes.

Beck-Winchatz and Riccobono discussed how the National Federation of the Blind’s National Center for Blind Youth in Science (NCBYS) and the National Aeronautics and Space Administration (NASA) worked together to develop initiatives consisting of hands-on science experiences for BLV students, including summer Science Academies, the Excellence through Challenging Exploration and Leadership (EXCEL) summer internship program for college students involving mentoring opportunities with blind scientists and engineers, and tactile astronomy books. The NFB Youth Slam, sponsored by the NCBYS, later evolved from the summer Science Academies into tracks
including life sciences, rocketry, and chemistry. Another partnership mentioned by Beck-Winchatz and Riccobono, between DePaul University of Chicago, Yerkes Observatory, and the Wisconsin Center for the Blind and Visually Impaired, created two summer astronomy camps for blind students. Astronomical objects were studied and the observatory telescopes were used to take visuals of constellations, which were later converted into large-print and tactile images.

All of the programs discussed by Beck-Winchatz and Riccobono were intended to assist BLV students in overcoming their educational and social isolation. Such programs are necessary to provide more accessible materials to blind students. These resources and collaborations are opening new doors of opportunity for blind students to develop stronger interests in STEM education and are furthering the development of the community of blind youth interested in science.

Summary

This literature review illustrated numerous theories and methodologies for teaching students who are blind or visually impaired in the subjects of chemistry, biology, physics, and general science. The concepts outlined addressed laboratory as well as lecture accommodations. Some of the techniques were low-tech solutions to accessing concepts, such as the periodic table discussed by Smith (1981). Some were high-tech solutions, such as the use of computer interfaces with laboratory probes and other external devices, including those discussed by Salt et al. (1980), Lunney and Morrison (1981), Morrison et al. (1981), Cartier and Jones (1988), Lunney (1994), Lunney et al. (1996), Milchus and Goldthwaite (2000), and others. Certain older technologies covered
in this review are no longer available commercially, but laid the groundwork for newer, more modern tools to be developed based on similar principles.

However, the major limitation of these efforts to date is the general lack of rigorous research studies on the efficacy of the techniques and technologies illustrated, with the exception of a relative few (Struve et al., 1975; Horowitz et al., 1987; Sevilla et al., 1991; Sahyun, 2000; Pence et al., 2003; Mayo, 2004; Ely et al., 2006). In fact, many of the papers from the first half of the 20th century were primarily the opinions, theories, and ideological statements of the writers and contained few specific suggested adaptations. Many of these early educators of the blind also focused on biology, neglecting the physical sciences, often due to a belief that physical science was out of the reach of blind students.

But technological and methodological adaptations have advanced a long way in recent decades, along with greater understanding of the true capabilities of blind students. The purpose of the ILAB study, while including the best aspects of previous researchers’ work, was to further contribute formalized research to the educational community about how best to use various access technologies and incorporate them into science curricula in high schools and colleges. The ILAB project is about empowering BLV students to participate as equals in their science laboratory groups toward the goal of eventual full inclusion as professionals in the sciences.

As Barraga (1990, p. 11) said, “The primary challenge … is to bring together the knowledge available with the best possible practices so as to produce quality products: adults with visual impairment who can move step-by-step up the ladder toward greater independence, freedom, and dignity commensurate with their ability.”
Chapter 3

Factors in Fostering Students’ Interest in STEM Education: Hands-On Science, Acceptance, Achievement

Hands-on approaches to learning sciences or related subjects may increase students’ interest and comprehension in the classroom, both for students who are blind and those who are sighted. As Rutherford and Ahlgren (1990, pp. 186-187) indicated in Science for All Americans, students learn best through multiple channels of sensory feedback – tactile, auditory, kinesthetic, or otherwise – and they more effectively retain what they have learned when they have had the opportunity to explore concrete examples within an appropriate context. The more success they experience with learning, the more self-confidence they have in their studies, which leads to further success in building new learning on the foundation of previous learning.

Although very little research has been conducted to specifically investigate the level of usefulness of hands-on learning approaches for students with BLV, some published works incorporated students with various disabilities. However, a breakdown of the specific types of disabilities often was not indicated. This limitation must be factored into the conclusions reached by the various authors.

The following sections discuss how hands-on approaches to teaching scientific concepts at various grade levels can impact students’ learning and increase their levels of interest and motivation in science classes. Also, students’ ability to feel accepted within group activities is reviewed and related to their academic achievement.
Hands-On Approaches to Learning

In her dissertation, *Science Curriculum Improvement Study (SCIS): Its Effect on Concept Development and Manipulative Skills in Visually Handicapped Children*, Long (1973) investigated the use of BLV adaptations to the Science Curriculum Improvement Study (which had originally been designed for sighted students) and their effect on learning basic scientific concepts and manipulative skills for children who were blind or low vision. This study was conducted at two locations: American University in Washington, D.C., and California State University in San Francisco. The 14 Washington students were the experimental group, and the 16 California students were the control group not exposed to the adapted SCIS. The students were bussed from their local schools to participate in a one-hour, hands-on laboratory session each week for 20 weeks. Pre- and post-tests were administered to both groups to measure science learning. Detailed observation sheets were filled out for each student during each session by the study’s observers. Some difficulties with regard to how the rubrics were implemented were found between observers. Socioeconomic, ethnic, and intelligence data (in the form of measured IQs) were compiled for each subject in the experimental group, and those in the control group were closely matched to the experimental group in these characteristics. Long concluded that the students who had been exposed to the hands-on SCIS experience had acquired more understanding of scientific concepts and developed better manipulative skills as compared to the students in the control group.

In “Adapting Science Material for the Blind (ASMB): Expectation for Student Outcomes,” Linn and Thier (1975) discussed the development and usefulness of the *Adapting Science Material for the Blind* curriculum, which the adapted version of the
SCIS had come to be called by that time. Linn and Thier noted that Piaget’s (1970) groundbreaking theories on the educational development of children included the concept that direct, frequent interaction with physical surroundings was necessary for the development and advancement of logical reasoning. The authors additionally noted the theories of Ausubel (1963), who stated that children learned best when new information was closely related to prior knowledge or, in other words, built upon and was similar to what they had already learned.

The SCIS, as described by Linn and Thier, was a curriculum for elementary school students consisting both of physical and life science units that were sequential, in that later units built upon earlier units. Students were not graded. The units used a range of objects and organisms to increase students’ interactions with their environment in the hope of promoting science learning. The ASMB, developed from the SCIS curriculum at the Lawrence Hall of Science at the University of California-Berkeley, was designed to be highly hands-on. The intent of the ASMB was to provide students having blindness with science experiences similar to those of their sighted counterparts performing similar activities. The ASMB was field tested in a number of classroom environments, both in residential and mainstream schools, including classrooms containing only children with visual impairments, mainstream classrooms incorporating one or more students with BLV, resource rooms for children with BLV, and situations in which students were deemed to benefit from more individualized, one-on-one instruction.

Linn and Thier found that, while using the ASMB in science classes, students with visual impairments required no more help than they did in their other classes. In many instances the students with visual impairments participated in the same activities as
their sighted counterparts, with only slight adaptations to include more audible and tactile indicators that allowed them the same opportunities to collect and observe information as the sighted students had. The authors also found that students with visual impairments tended to take more time to investigate the ASMB objects as compared to sighted students, and tended to discuss them more than did the sighted students.

A series of evaluation measures were used to determine the effectiveness of the ASMB. These were manipulative measures, concrete measures, and process measures. The manipulative measures involved the basic handling of objects and organisms, and dealt with matters such as pouring liquids and measuring liquids using syringes. The concrete measures included describing an organism’s environment and detailing a complete system for a scientific concept. The process measures consisted of giving explanations and interpretations, and making hypotheses about scientific questions. Linn and Thier found that the students with visual impairments using ASMB improved in all three measures, but the largest improvements were in the areas of manipulative and concrete skills.

In another evaluation discussed in the same paper, Linn and Thier reported that students using the ASMB for the first time made improvements in all three skills areas. However, they noted that when comparing the pre-test/post-test scores to those of sighted students, the pre-test scores of students with visual impairments were much lower than those of the sighted students, and their post-test scores were comparable to the sighted students’ pre-test scores. In a further evaluation, of students using ASMB for a second year, the students with visual impairments were divided into two groups: low ability and medium-to-high ability. The students in the medium-to-high-ability group were found to
improve in all three skills areas. However, the low-ability group improved in
manipulative and concrete skills only. Linn and Thier concluded that students with visual
impairments can make immediate gains in at least two of the three skills areas when
placed in an experiential science program, thus reinforcing Piaget’s (1970) theories of
child development regarding environmental interaction as being vital to improving
reasoning skills.

Davis and Black (1985/86), in “Student Opinion of the Investigative Laboratory
Format,” discussed how a Biology 1 laboratory course at the University of California-
Davis during the fall, winter, and spring quarters of 1982-83 was designed to give
introductory students the opportunity to work individually on their own experiments,
ranging from chemical biological analysis to behavioral studies. Each student participated
in an Individual Experiment in four phases: a planning stage, experimentation, analysis,
and presentation. The experimentation and data collection lasted from several days to a
number of weeks. After analysis, the students each gave a five- to ten-minute seminar for
the rest of the class regarding their findings.

Six hundred students were surveyed to determine the value of this Individual
Experiment experience, with a focus on the ability of the students to better understand the
scientific method and to design future experiments (Survey 1). During the winter quarter
of 1983, another 600 students who had already completed Biology 1 and advanced into
one or more of seven higher biology classes were surveyed (Survey 2). Many Survey 1
students were resurveyed in this follow-up investigation. Both Survey 1 and Survey 2
attempted to measure whether and by how much the Biology 1 hands-on Individual
Experiment approach, as compared to the traditional structured-exercise approach, had positively impacted students’ levels of interest in biology classes.

The results showed that the hands-on investigative laboratory format engaged students directly in the process of using the scientific method and assisted them in their completion of laboratory investigations. According to the results from both surveys, approximately two-thirds of the students found the Individual Experiment approach to be more beneficial than the conventional laboratory curriculum.

A literature review by Scruggs and Mastropieri (1993), “Current Approaches to Science Education: Implications for Mainstream Instruction of Students with Disabilities,” commented on the challenges of educating students with various learning and physical disabilities, including visual impairments. Specifically, these authors were interested in examining two contrasting approaches to teaching science: the content-oriented approach, which depends heavily on textbook-based lessons and factual recall of principal components during learning assessments, and the activities-oriented approach, involving more hands-on manipulations and performance-based learning assessments. The authors outlined the literature supporting the contention that students with disabilities could learn effectively through hands-on approaches. However, they stated that both the content-oriented approach and the activities-oriented approach to teaching science could enhance the students’ ability to learn, depending on the nature of the disability and whether any adaptations were appropriately designed and presented. Therefore, they said, the curriculum and its adaptations for students with disabilities must be sensitive to the individualized needs of the students.
Scruggs and Mastropieri pointed out that students’ disabilities could inhibit science learning. They also found that although content-oriented approaches occasionally used hands-on science activities or teacher demonstrations to reinforce the content covered in textbooks, it was rarer for such activities to be used as true ‘scientific method’ explorations to investigate scientific questions in process-oriented learning. Additionally, Rutherford and Ahlgren (1990), as cited in Scruggs and Mastropieri, indicated that content-oriented approaches cover a wide range of material but in little depth, while activity-oriented approaches address topics in greater detail but necessitate inclusion of fewer topics due to the greater time requirements.

Scruggs and Mastropieri stated that students participating in activities-oriented approaches are often evaluated on their direct involvement with the phenomena being observed according to performance-based criteria. Further, such assessments are designed to minimize the use of specialized vocabulary and rely on students’ ability to use materials to answer scientific questions rather than the memorization of content from lengthy textbook readings. Also, they said science teachers’ level of skill in using either the textbook-based or activities-based approach, or a combination of the two, would positively or negatively impact the students’ learning experience. They concluded that students with disabilities may benefit from a hands-on, activities-based approach to science learning with appropriate customization of the content in question.

Further work by Mastropieri and Scruggs (1994), “Text Versus Hands-On Science Curriculum: Implications for Students with Disabilities,” investigated the differential usefulness of the hands-on science activities approach as compared to the textbook-based approach. There were four schools in this study, two of which used an
activities-oriented approach, and the other two used a textbook-oriented approach. The grades studied were kindergarten through sixth. Mastropieri and Scruggs analyzed and evaluated the curricula for each school, applying numerous categories of investigation for each type of approach and grade level. Their findings indicated that students with disabilities could learn from either approach but that curriculum adaptations and modifications would play integral roles in students’ level of success. They stated that when school districts choose a science curriculum, the needs of the schools’ special-education populations should be taken into account in deciding which approach to use. These authors also felt that performance-based assessments and content-based assessments were necessary and both should be included for either approach.

A study at Rensselaer Polytechnic Institute by Carlson et al. (1995), “Evaluating a Motivational Freshman Course,” discussed a freshman engineering class called Introduction to Engineering Electronics (IEE), which was designed to use a completely hands-on approach to teaching by including no formal lecture. The study involved a total of 93 students, divided into two sections in subsequent semesters. After completion of the course, attitudinal surveys were conducted along with structured interviews to determine the students’ levels of interest in electrical engineering. Then these students were tracked through a second course, Introduction to Engineering Design, and were further interviewed to determine their motivation to continue studying engineering in the future. The data indicated an increased interest in electrical engineering and motivation to continue in the electrical engineering program. Answers to survey questions related to the hands-on approach of the IEE course revealed that this format significantly influenced the students’ interest and motivation in electrical engineering.
Paris et al. (1998) reported on a study of third-, fourth-, and fifth-grade students all from the same school in a six-week biology curriculum, in “Hands-On Biology: A Museum-School-University Partnership for Enhancing Students’ Interest and Learning in Science.” The study involved a collaboration between the primary school, a local science museum, and a local university. The sample size was 184 children. The Hands-On Biology activities were designed to encourage a greater interest in science. These laboratory activities included growing plants, examining living exhibits such as those containing tadpoles and butterflies, and investigating the properties of eggs, bones, and fossils, among others. Science attitudinal surveys were conducted pre- and post-activity. Weekly quizzes were administered to test retention of understanding. The authors found that the more the activities could be related to everyday life, the more the students tended to remember. They also found that the hands-on activities as a whole significantly contributed to the students’ learning experiences, and enhanced their motivation and interest in science.

Carlson and Sullivan’s “Hands-On Engineering: Learning by Doing in the Integrated Teaching and Learning Program” (1999) reported on the new Integrated Teaching and Learning (ITL) program and laboratory for engineering students at the University of Colorado at Boulder. ITL provided a state-of-the-art, hands-on learning environment for engineering students at all levels and in various engineering majors. The university was successful in obtaining research funds to provide a cutting-edge computer infrastructure to give students access to technologies they would otherwise not have had. According to Carlson and Sullivan’s preliminary figures, using the ITL in the heavily hands-on First-Year Engineering Projects course led to a substantially increased number
of students being retained in engineering majors into the third year of their undergraduate programs (80% retention versus only 55% prior to the creation of the ITL). The goal of this facility was to provide a more interactive and experiential learning environment for students to explore design and technical skills in various engineering fields, and it appeared to be highly successful in this regard.

“The Role of Interest in Fostering Sixth Grade Students’ Identities As Competent Learners,” by McPhail et al. (2000), investigated how the academic interests of sixth-grade students could be used to design curricula to further foster these interests in the hope of increasing the students’ confidence in themselves as competent learners. As cited by McPhail et al. and paraphrased herein, Dewey (1938) indicated that the elimination of a hands-on approach to learning could minimize student motivation and achievement. Among other findings, the authors affirmed Dewey’s position.

McPhail et al. explored three research questions in this work. The first dealt with how sixth-grade students discuss their learning interests; the second addressed the nature of sixth-grade students’ levels of engagement in subject-focused activities for their self-indicated primary and secondary interests; and the third investigated the applications of this research for fostering the students’ meaningful involvement in their chosen areas of interest. The researchers used student brainstorming sessions, focus-group sessions, and individual interviews with the participants to ascertain the students’ areas of interest and their preferred methods of learning. Based on the feedback received from the early sessions, the students were divided into six interest groups: animals, computers, drama, fitness, social studies, and science. Participants consisted of 47 children at a Midwestern U.S. rural school.
For the students who expressed a strong interest in science, McPhail et al. found they were 2.5 times more likely than the rest of the class to want to learn through direct interaction with the activities or, in other words, through an experiential or hands-on approach. Results indicated that hands-on science experiences helped these students better understand the concepts. While the class as a whole indicated that an experiential approach to learning was preferred, this effect was stronger in the science group. The researchers also found that context-based learning was more meaningful to students and aided in student understanding and recall of information. The authors stated (p. 61), “There is a sense of these students wanting to understand the physical world through direct action on it,” and concluded that identifying students’ primary areas of interests, then employing instructional methodologies that fostered these interests, would help students understand and recall information more easily and thus come to see themselves as competent learners.

A dissertation titled *Hands-On Science and Student Achievement* by Ruby (2001), from the RAND Graduate School, focused on three questions related to hands-on science approaches to learning and whether there was a potential positive relationship between hands-on science and student achievement. He predicted that students who engaged in more hands-on science activities would perform at higher levels than would students who participated in fewer such activities, with all other aspects being equal.

Ruby further investigated whether there was a differential relationship of the effect of participating in hands-on science for students with higher versus lower academic ability. He predicted that students with higher ability would achieve greater success from hands-on science activities. He also stated that, since hands-on science makes abstract
concepts into more clearly defined representations, this approach could assist lower-ability students in their understanding and thus lead to increased achievement scores.

Ruby used two main data sets, selected because he felt they complemented and supplemented each other. The primary data set was the 1994 RAND Survey of approximately 1,400 eighth-grade students and their teachers in southern California. This instrument looked both at multiple-choice test scores and performance test scores. The strength of the RAND Survey, according to Ruby, was that it included both types of assessment tests, thus allowing for the comparison of hands-on science in each type of assessment. Both types of tests were taken by the same students. The performance tests were based on hands-on activities the students conducted; the students were also required to write up their observations and answer follow-up questions. Additionally, the RAND Survey included reports from teachers and students as to the amount of hands-on science used in the classroom.

The second data set was the National Education Longitudinal Survey 1988 (NELS:88), comprising a nationally representative sample of students. The NELS:88 data used by Ruby looked at eighth-, tenth-, and twelfth-grade students during the 1988, 1990, and 1992 school years, although Ruby focused most on the eighth-grade sample. (The NELS:88 again surveyed the same students in 1994 and 2000, but Ruby did not include this later data.) The NELS:88 involved hands-on science in the classroom, and included teachers and students, longitudinally surveying its subjects initially over a five-year period in even-numbered years. This data set involved approximately 25,000 students and teachers, but only 11,000 students were asked about science. The NELS:88 employed
achievement multiple-choice tests in the areas of reading, social studies, mathematics, and science (National Center for Education Statistics, date unknown).

Ruby found that the eighth-grade data for the RAND Survey and the NELS:88 data at the eighth- and tenth-grade levels indicated a positive correlation between hands-on science activities and test performance. However, this correlation was not observed in the NELS:88 data for twelfth grade. The NELS:88 also revealed that students of higher socioeconomic status (SES) achieved higher multiple-choice and/or performance test scores than did those of lower socioeconomic status. Ruby observed that students of higher SES tended to have had more hands-on science experiences.

For Ruby’s hypothesis 1 (“whether hands-on science is positively related to student achievement as measured by standardized test scores using both multiple choice and performance tests”), he concluded that when comparing the NELS:88 to the RAND Survey, it was difficult to draw a link between hands-on science and student achievement. He felt that more data would be necessary before a conclusion could be made. With regard to hypotheses 2 and 3 (“whether this relationship is stronger when using performance tests” and “whether this relationship differs by student ability”), Ruby concluded there was little evidence to support them. In summary, Ruby did not definitively state a positive link between hands-on science activities and student achievement on performance and multiple-choice tests, but said such a link might be supported through further research in this area.

The Greater Capital Region DNA Science Project Survey Results (2002), produced by the Greater Capital Region Teacher Center (GCRTC) headquartered at the University of Albany in New York, revealed the results of a teacher survey on the
The efficacy of the GCRTC’s DNA Science Project curriculum. At the time, the GCRTC served 22,000 educators in 93 school districts and 68 private schools in the state of New York. The purpose of this evaluation was to determine to what level the program had influenced teachers and students, and to discover what challenges needed to be addressed to further improve the curriculum’s effectiveness in future years. While the DNA Science Project was originally offered only to gifted students, in 2002 it was decided that all students would receive education on DNA to meet the requirements of new state-mandated tests. The survey also investigated the GCRTC’s level of support for teachers and tried to determine whether more support was required to meet teacher needs.

A survey was mailed to 125 biology and life-sciences teachers in the region; 52 surveys were completed and returned. The majority of the returned surveys were from high school science teachers, with some junior high teachers also participating. The majority of the respondents provided positive feedback on the use of the DNA Science Project, saying that the curriculum had helped them become better teachers. Among the many categories of results, the survey indicated that 73% of the respondents felt the DNA Science Project offered increased hands-on science activities for students, which increased students’ interest and motivation to learn biology and life-sciences concepts. These teachers reported that their students demonstrated they could remember the hands-on activities more easily, which raised their levels of enjoyment of the course materials. Also, approximately half the teachers in this data set indicated they observed a higher number of students taking an interest in becoming scientists in the areas of biotechnology, molecular biology, and other related life sciences as a result of having participated in the DNA Science Project.
Reynolds (2004), in a paper titled “On the Practical Aspects of Incorporating Field-Based Projects into Introductory Oceanography,” discussed how an introductory oceanography class was adapted to include a series of hands-on science activities and how resultant student learning was measured. A concept inventory test was administered at the beginning of the course to determine how much the students already understood. Based on this feedback, the instructor then customized the course curriculum.

The oceanography class consisted of three lecture periods and one laboratory session each week. Reynolds’ data was from three courses conducted over three years, each comprising 48 students. All students were expected to gain a full understanding of how the oceanography equipment worked and of the analysis techniques used. Teams collected and analyzed various materials, through activities such as gathering and examining bottom samples. The teams of students were kept small to ensure that all members of each group had the opportunity to experience all aspects of every project. This approach also led to a better understanding of the equipment used and the scientific concepts involved in the course projects. At the end of the course, the students were reevaluated on the concept inventory test and were asked to self report their level of confidence regarding their answers. Results of the post-tests indicated that the students came out of this hands-on science experience with increased confidence in their own abilities and in the technology used, more positive attitudes toward science, and substantially increased scientific understanding.

Extending the concept of hands-on oceanography to students with visual impairments, Fraser (2008) in “Oceanography for the Visually Impaired” discussed a series of hands-on activities and experiences for a group of high school students at the
Perkins School for the Blind in Watertown, Massachusetts. This article described how the students successfully interacted with oceanography equipment throughout a series of hands-on activities including data collection. These students also received a tour of the famous ship R/V Knorr, where they had the opportunity to examine oceanographic equipment to be used on an upcoming sea expedition. Additionally, they were given a tour and allowed to handle sea creatures and bones from whales and other organisms at the Woods Hole Oceanographic Institute.

As part of this hands-on experience, the students, accompanied by their science teacher, were allowed to design some oceanography experiments and test them at Woods Hole Harbor aboard a ship called the Ocean Quest. The students had the opportunity to be mentored by an oceanographer with BLV throughout this entire process. They also were asked to design some experiments for professional oceanographers to conduct on an upcoming expedition to the Labrador Sea. Their science teacher from Perkins accompanied the oceanographer with BLV on this expedition to gather data, and maintained contact with her students by way of digital audio recordings and satellite telephone. The students received audio descriptions of the samples being collected and had the opportunity to interact with scientists on the expedition. Because of these hands-on and interactive experiences, the students were excited about having an impact on a real oceanography expedition. The project gave the students ideas as to how they could participate in this scientific field not generally thought possible for students with BLV.

Lynch et al.’s “Effectiveness of a Highly Rated Science Curriculum Unit for Students with Disabilities in General Education Classrooms” (2007) reported on a study of the effectiveness of the Chemistry That Applies (CTA) curriculum for teaching science
to diverse middle school students, particularly focusing on those with disabilities. The students were from the Montgomery County Public Schools system in Maryland, which had over 136,000 students. The sample consisted of 2,282 students from 10 schools, with five schools having implemented the CTA curriculum and the other five being the comparison group. Of these students, 202 had reported disabilities, of which 99 were in the comparison group and 103 in the experimental group.

The CTA was developed at Michigan State University. It was designed for eighth-to tenth-grade students and took six to 10 weeks. It consisted of four units, although only three were used in this study as the researchers felt the fourth unit was inappropriate for middle school students. This study occurred over one school year – the second year the school district had implemented the CTA. The units consisted of a number of hands-on activities dealing with the conservation of matter, such as students using ball-and-stick models to understand how molecules and atoms are constructed and interact with one another. Also explored were phenomena such as sugar dissolving in water and the melting of ice. These activities allowed the students to physically interact with the materials being examined. The objects and chemicals used were common household items, such as Alka Seltzer pills, balls of steel wool, and butane lighters.

One limitation of the Lynch et al. work is that it presented findings for all students with disabilities together, and did not separate out students with specific disability types because the school district had not recorded individual disabilities. Nevertheless, the investigators found CTA to be as effective for students with disabilities as for students without disabilities. They reported that the majority of students, both disabled and not, who used the CTA curriculum had scored significantly higher on the post-tests than on
the pre-tests as compared to the control group. This work illustrated how hands-on science activities can positively benefit all students, including those with various disabilities.

A master’s thesis by Osmar (2008), titled *Using Alternative Energy Concepts and Hands-On Activities to Teach Physics Benchmarks and Increase Student Motivation: Thermodynamics, Optics and Electricity*, investigated how hands-on laboratory components of a high school physics class could impact students’ interest and motivation in learning. The students conducted numerous experiments in units involving thermodynamics, optics, and electricity, such as measuring the boiling point of water, completing circuits, designing photovoltaic cells, making small rockets, and more. This study found the hands-on experiences succeeded in raising the interest, engagement, and motivation of the students during laboratory sessions and classroom discussions. Students tended to be genuinely involved in the brainstorming sessions, laboratory explorations and activities, and post-lab discussions about what had been observed. However, when it came to laboratory write-ups and in-depth thinking about why phenomena had occurred, the students lost interest. Osmar suggested that the general lack of motivation toward understanding concepts may have been due to the fact that many of the students in the study had historically been underachievers and were accustomed to exerting little effort. She stated that several changes in how laboratory procedures are written, designed, and presented might improve future results.
Summarizing the Hands-On Literature

Overall, the preceding authors indicated that hands-on science experiences often prove helpful to student learning. This literature represents various populations of students in elementary school, middle school, high school, and college. These works covered a wide range of academic subjects including general science, chemistry, biology, physics, oceanography, and engineering. Although many of the students in these works were not disabled, several studies included students with visual, cognitive, and other disabilities. These works document how hands-on science learning experiences can positively impact student learning for all these populations. Although Ruby’s and Osmar’s findings were partially inconclusive on whether or not hands-on experiences positively impacted student learning, a lot of their work was suggestive of the premise that hands-on learning may be beneficial.

Student Learning: Group Dynamics and Peer Acceptance/Rejection

The previous section outlined how hands-on science learning can improve academic achievement. Also, as noted by many of the authors (Davis and Black, 1985/86; Carlson et al., 1995; Paris et al., 1998; Carlson and Sullivan, 1999; Greater Capital Region DNA Science Project Survey Results, 2002; Reynolds, 2004; Fraser, 2008), hands-on science experiences can foster student interest, which often leads to achievement. Other factors that can encourage or squelch student interest and achievement in science learning include group dynamics and peer acceptance/rejection, both for the disabled and nondisabled.
A literature review by Van Hasselt (1983), “Social Adaptation in the Blind,” discussed the social interactions and characteristics of persons with blindness. Blindness was found to be an isolating condition that could negatively impact the psychological well-being of children and adults. Van Hasselt stated that these children’s use of facial expressions, gestures, postures, vocal tone, and other social actions were not well developed. Also, children with blindness tended to exhibit behaviors not found within sighted populations, such as rocking, hand flapping, and inadequate grooming and hygiene. These differences could further isolate children with blindness from their sighted counterparts. Van Hasselt concluded that more social skills training needed to be provided to students with blindness to aid them in their acceptance into society, including classrooms. He stated that the earlier these interventions were provided, the more successful they might be.

In “Polarized Socialization in an Urban High School,” Shimahara (1983) investigated how placing students in stratified groups on the basis of perceived levels of academic ability impacted their class participation and achievement, and how race played a part in these groupings. In each academic subject, the students were divided into five sections, with the exceptional students in Section I, above average in Section II, average in Section III, below average in Section IV, and “adjusted” in Section V. This sectioning was based on class grades, performance on achievement tests, and other criteria. It was observed that the majority of African-American students were placed in the lower-ability sections, and only a very small number were in Sections I and II. Expectations for the students (originating both from the students themselves and from the educators) were significantly different from section to section, with very little being expected of the
students in the lower-ability sections. These expectations impacted the levels of achievement the students were capable of reaching.

Shimahara defined the term “cultural capital” as a person’s knowledge base that impacts their societal interactions. He implied that the levels of cultural capital available to the students in the various sections were quite different, affecting their receptiveness to learning and thus further fostering or limiting their educational opportunities. He stated that, due to the sectioning, the students did not have equal access to educational content.

While this research was partly about race, the work clearly supports the contention that labeling groups of students according to expected abilities fulfills the expectations of the label. Extending Shimahara’s implications, it may be stated that if students who are blind or low vision, or otherwise disabled, are placed into a group with low expectations, they likewise may be motivated only to the level of expectation. This statement is further confirmed by Rutherford and Ahlgren (1990, p. 187), who indicate that students only learn up to the level that they and their teachers, other educational staff members, and parents have for them.

A study by Austin and Draper (1984), “The Relationship Among Peer Acceptance, Social Impact, and Academic Achievement in Middle Childhood,” involved 145 children in grades three through six from an Iowa elementary school. The authors investigated the connections between four categories of social status (popularity, amiability, rejection, and isolation) and academic achievement. Students were asked a set of written questions about whom they liked to play with, sit beside in class, and participate with in activities, and whom they did not. Austin and Draper used the results to place each student into one of the four social status categories. The students were also
divided into above-average achievers and below-average achievers based on their scores on a standardized achievement test.

Each student’s social status categorization was then correlated with their academic achievement grouping. Among the findings were that 28% of the students in the high-achieving group were popular, whereas only 11% of the lower-achieving students were in this category, indicating that achievement could be linked to popularity. The “rejected” category contained 16% above-average students but 37% below-average students, showing a strong connection between poor academic achievement and rejection by other students. While Austin and Draper did not discuss students with disabilities, it can be inferred from their research linking academic achievement or non-achievement to peer acceptance or rejection in elementary school, rejection by peers and low achievement among students with disabilities are likely to be closely correlated.

Tamir’s article, “Home and School Effects on Science Achievement of High School Students in Israel” (1989), discussed significant factors that could impact high school students’ learning as related to achievement in science. This study had a sample pool of 2,277 twelfth-grade students in Israel from 68 high schools. A number of data collection instruments were used. Among these tests were the Student Background Questionnaire, Science Test 3M, Specialized Achievement Tests, Description of Instructional Strategies, and the Attitude Scale.

The Student Background Questionnaire inquired about school-related practices, home environment, and future aspirations regarding college and career. The Science Test 3M involved questions from four subject areas: earth science, biology, chemistry, and physics. The Specialized Achievement Tests were in the areas of biology, chemistry,
physics, and non-science, based on individual students’ interests. The Description of Instructional Strategies consisted of students self-reporting on teachers’ actions in the classroom. The Attitude Scale measured students’ attitudes toward science.

Tamir found a high correlation between student interest/motivation and achievement in science. Specifically, the two most significant variables from the school environment, as related to achievement in science, were the opportunities to learn and the interest/motivation of each student. Tamir concluded that researchers and educators needed to design ways for students to understand science by increasing the quality of teaching strategies and methodologies in the classroom. The personal variables of interest/motivation were directly related to student achievement and were impacted by the quality of the instruction. The implications, according to Tamir, were that students’ interest/motivation impacted their desire to pursue careers in science and continue their education toward advanced degrees.

Pomplun (1996), in his work titled “Cooperative Groups: Alternative Assessment for Students with Disabilities?” conducted a statewide science assessment of students with disabilities working in cooperative groups with nondisabled peers. Disabilities included hearing impairments, physical impairments, mental development impairments, and blindness or low vision, etc. The assessment consisted of an objective individual component and cooperative group components. The cooperative elements involved teachers serving as facilitators while groups of students addressed open-ended scientific questions. The individual element involved a knowledge-based test administered after completion of the group projects.
Pomplun was interested in the scores of fifth-grade students in Kansas. The study was administered in the spring and fall of 1994. There were 888 students with disabilities in 777 groups consisting primarily of nondisabled students, with 104 groups including more than one student with a disability. One of the major questions of this study addressed whether students with disabilities negatively impacted group performance.

Pomplun found that the groups’ levels of achievement were higher than expected. However, the individual assessments after completion of the group projects showed that the students with disabilities scored lower than their nondisabled counterparts. This finding may indicate that the students with disabilities did not actively participate in the group activities. Six students who were blind or low vision were included in this study. The groups incorporating the students with visual impairments had the lowest cooperative group scores.

Most importantly, however, when the data were compared with those of groups not containing students with disabilities, Pomplun found that the groups containing at least one student with a disability did not score lower than the homogeneous groups. This indicated that students with disabilities did not adversely affect overall group performance. He stated more research was necessary on individual types of disabilities and how specific accommodations for students with disabilities could impact group achievement.

An article by Wentzel and Caldwell (1997), titled “Friendships, Peer Acceptance, and Group Membership: Relations to Academic Achievement in Middle School,” tracked two groups of middle school students to observe their relationships with peers and relate these relationships to academic achievement. Study 1 followed 213 students from the
sixth grade to the seventh grade, measuring peer acceptance, reciprocal friendships, and group membership. Study 2 examined the same three aspects but extended the investigation to include measurements of prosocial behavior, antisocial behavior, and emotional distress, and explored how these behaviors affected the other measurements. Antisocial behaviors ranged from students breaking classroom rules to simply not doing what they were supposed to do. Prosocial behaviors consisted of students helping others to understand concepts and performing similar positive actions within the classroom environment. The Study 2 sample comprised 404 sixth-grade through eighth-grade students.

Wentzel and Caldwell found that group membership was the most significant predictor of academic achievement. Peer relationships and reciprocal friendships also contributed. Students exhibiting prosocial behaviors tended to experience higher levels of achievement, while students exhibiting antisocial behaviors tended to not perform as well. This work further supports the concept that group acceptance directly impacts student achievement.

For a dissertation titled *Task Enjoyment and Mathematical Achievement*, Heine (1997) studied 220 talented or gifted seventh- and eighth-grade students over a four-year period. Talent or giftedness was determined based on individual students’ Scholastic Aptitude Test (SAT) scores. When the top 1% of gifted students’ academic performances was explored, no consistent relationship was found. However, when the study sample was increased to include the top 5% of students, a relationship between task enjoyment and mathematical achievement was confirmed.
Heine also found that “flow” was a prominent factor in academic achievement. Flow was defined as deep engagement in a task, such as when a student worked on a task for an extended period of time that seemed to the student to pass in only minutes. With flow, distractions go unnoticed and all mental energy is focused on the task. Flow was measured by students’ self-reporting at three times throughout the school year on instruments referred to as Forms A, B, and C. The forms contained 10 to 26 Likert-scale questions about the students’ ability to focus on the tasks at hand and also measured cognitive ease and task enjoyment. Heine found that as flow increased, higher levels of motivation were attained, which led in turn to greater achievement. He cautioned that, when the goals and methodologies of a curriculum are not able to motivate talented students, the curriculum can be detrimental to learners by not meeting their academic needs and leading to lower levels of achievement. He found that gifted learners should be presented with a challenging curriculum to encourage their experience of flow and thus increase their task enjoyment and academic achievement.

Pearl et al. (1998), in “The Social Integration of Students with Mild Disabilities in General Education Classrooms: Peer Group Membership and Peer-Assessed Social Behavior,” studied the social integration of elementary students exhibiting mild disabilities in 59 classrooms. The sample included 198 students with disabilities among a population of 1,538 in the fourth, fifth, and sixth grades. Three variables were investigated: peer-group membership, peer-assessed behavioral characteristics, and the peer-assessed behavioral characteristics of their group members. The main focus was to compare the peer-perceived behaviors of students with mild disabilities to those of their nondisabled counterparts.
Pearl et al. found that approximately 20% of the students with mild disabilities were socially isolated. These students differed from their nondisabled counterparts in the area of peer-assessed behavioral characteristics, impacting their acceptance into peer groups. There was a high representation of these students in antisocial peer groups and an underrepresentation of them in prosocial peer groups. Pearl et al. stated that students who fell into the antisocial category may have required social skills training. They said students with mild disabilities should be encouraged to interact with students that exhibit prosocial behaviors.

It was not the point of Pearl et al.’s study to investigate how different types of disabilities impacted social integration. Instead, the focus of this work was to observe how peer-assessed behaviors could influence where students with mild disabilities were positioned within the social network of the classroom. Students with mild disabilities were often classified by their peers as being shy and needing more help. The authors cautioned that these results should not be generalized across all students with disabilities. They stated that additional research was necessary within specific disability groups to understand the social impact on students with various disabilities and on their nondisabled counterparts. This work indicated a need for interventions to be developed to enhance the social dynamics of students with disabilities within general classroom populations.

An article by Webb et al. (2002), titled “Short Circuits or Super Conductors? Effects of Group Composition on High-Achieving Students’ Science Assessment Performance,” investigated group ability composition by comparing homogeneous vs. heterogeneous academic ability groups. The work was an extension of an earlier study of
662 eighth-grade students in 21 classes in five schools in Los Angeles County (Webb et al., 1998). The 2002 study looked at students in the academic top 25%, classified as having high ability. Three of the schools were excluded for various reasons, thus leaving 83 students from nine classes in two schools.

The participants were given three phases of assessments. Phase 1 tests were administered in the areas of vocabulary and verbal and nonverbal reasoning. Once this was completed, all the teachers conducted a unit on electricity. This was followed by Phase 2 testing, which consisted of a hands-on practicum illustrating the relationships learned in the electricity unit along with a written test on the same material. All assessments were carried out individually by each student. These same assessments were readministered one month later in Phase 3a and 3b, and consisted of collaborative group work for the hands-on component (3a) and individual work for the written tests (3b).

Webb et al.’s study focused on the importance of collaborative group assessment as compared to individual assessment. There were three key findings in this study. High-ability students performed well in homogeneous groups and in some heterogeneous groups, but not in all heterogeneous groups. The quality of group interaction was the major predictor of student performance. The higher-ability students had varying capabilities to work well with lower-ability students, which directly impacted the functionality of heterogeneous groups. Thus, this study illustrated how group composition can play an integral role in students feeling accepted or not accepted by their peers, thereby influencing the group and its members to achieve lower or higher levels of performance. Often the students categorized as low-achieving were able to work
collaboratively with high-achieving students to perform tasks they might otherwise have never been able to accomplish.

Smerdon (2002), in “Students’ Perceptions of Membership in their High Schools,” investigated how student characteristics and various school aspects impacted the students’ perceptions regarding membership within the school environment. Specifically, Smerdon looked at three key factors, which were students’ feelings of belonging, students’ commitment to school, and students’ commitment to academic work. The sample population was taken from the National Education Longitudinal Study (NELS:88) for 1988 and the follow-up in 1990. The students were tracked from the eighth to the tenth grade. The sample comprised 11,807 students from 808 high schools across the United States.

One key finding was that students who were in need of school membership the most, and would have benefited from it the most, actually had lower levels of perceived membership than did their peers. One reason for this, Smerdon asserted, was that educational inequities often exist within schools. In other words, expectations are set higher for some students than for others, instead of schools setting high goals for all students. It was also observed that students who enrolled in more math and English classes and held higher expectations of educational accomplishment had higher perceived school membership than did their counterparts.

Students’ grades in middle school were found to be directly linked to academic achievement in high school. Their levels of perceived school membership likewise carried over from middle school to high school. Students who transitioned from middle school with low grades and exhibited negative academic behaviors perceived lower levels
of high school membership than did their peers. Students exhibiting higher perceived membership and better grades in middle school carried over these characteristics to high school. Students’ grades and perceived membership within middle school environments were found by Smerdon to be the most significant factors impacting academic achievement and perceived membership in high school. Additionally, students with higher levels of perceived membership in high school tended to have higher expectations for academic achievement as compared to students with lower perceived membership. Smerdon’s work implies that students’ acceptance within their school environments can directly impact academic achievement.

Anderman (2003), in “Academic and Social Perceptions As Predictors of Change in Middle School Students’ Sense of School Belonging,” discussed how students’ experiences of a sense of belonging in their school environment changes over time. The author looked at variables including grade point average, teachers’ fostering of respect between students, classroom orientation toward task goals, students’ assessment of academics as being useful and interesting, and personal expectancy for academic performance. In this study, 618 students participated in surveys administered at three time points: the spring of sixth grade, fall of seventh grade, and spring of seventh grade. The surveys focused on students’ perceptions of the environment in the classroom, peer and teacher relationships, and academic motivations and expectations.

Anderman found a decline in students’ sense of belonging across the three surveys: The longer that students were in the middle school setting, the more their sense of belonging and of feeling accepted in that environment decreased. However, the decline was tempered in environments that promoted aspects of self improvement and a focus on
mastery of tasks, as well as when students felt their schoolwork was interesting and important to them, and when teachers encouraged a sense of mutual respect between students. The author also found that students’ prior academic achievement positively impacted their feelings of acceptance. Anderman concluded that middle school interventions were necessary to ensure that students felt accepted in the school environment, but did not recommend specific types of interventions.

Chen et al. (2003), in “The Peer Group As a Context: Mediating and Moderating Effects on Relations between Academic Achievement and Social Functioning in Chinese Children,” investigated a large sample of Chinese adolescents at ages 9, 13, and 16 years. The authors examined how the contextual effects of peer groups were related to academic achievement and social functioning within the school environment. It was found in this sample that peer groups were very homogeneous in academic achievement. Chen et al. also found that academic achievement and social adjustment were related. The researchers looked at group academic norms as a framework for mediating and moderating the relationships between academic achievement and the social characteristics of individuals. While one limitation of this work is that there were no similar published data in Western cultures, much of the literature used as background for this study was from the West.

Chen et al.’s sample comprised 730 children in grades three, six, and ten in schools in Shanghai. The measures included peer assessments of social functioning, teacher ratings of social competence, positive/negative classmate nominations, leadership, academics, and peer groups. The researchers found that the positive or negative social interactions within a group contributed to the group’s level of
achievement. High group academic achievement was found to be strongly linked to high academic achievement among the individual group members. Higher levels of achievement were also directly linked to individual student acceptance within social groups. Therefore, academic achievement can be linked to students’ acceptance within their peer groups.

**Summarizing the Peer Acceptance/Rejection Literature**

The authors in this section vividly illustrated that peer acceptance is an important factor in student learning. This acceptance, including feelings of belonging, clearly aids in student interest and academic achievement. In turn, academic achievement was shown to aid in peer acceptance.

**Tying the Factors Together**

This chapter shows that multisensory science learning, including hands-on activities, leads to higher levels of student interest and academic achievement. Interest and achievement are also clearly linked to group dynamics and peer acceptance. Increased interest in science is related to greater academic achievement. As stated by Rutherford and Ahlgren (1990), multisensory learning and experiential approaches tend to increase students’ achievement in science.

As indicated by Van Hasselt (1983) and Pearl et al. (1998), students with disabilities tend to experience higher levels of rejection within groups than do their nondisabled counterparts. It is the assertion of this dissertation that increased multisensory and hands-on participation by students with blindness or low vision in
laboratory groups should lead to increased peer acceptance, interest in science, and academic achievement. Likewise, increased interest in science due to hands-on experiences should enhance the participation of students with BLV in science laboratory groups. Students with BLV tend to be more successful when they are accepted into their lab groups and other classroom learning environments.
Chapter 4

Methodology

The educational research study associated with the ILAB project consisted of various data collection tools and data analysis techniques. This work combined qualitative and quantitative methods. These two methodologies, while sometimes seen as dichotomous, are actually often used together in educational research to yield enhanced results.

What Is Qualitative Research?

Qualitative research looks at aspects that are not examinable through quantitative research (Adams, 2004; Ragin et al., 2004; Satterfield, 2004). Qualitative research involves observations from a limited number of cases, even as few as one, that may be unrepresentative of large populations (Collier et al., 2004; Maxwell, 2005; Ragin, 2004; Ragin et al., 2004). These cases are chosen for their uniqueness and interest to qualitative researchers. Ragin (2004) further defined qualitative research as making sense of cases selected for their social importance, while quantitative research is based on variables or questions of inference and predictions.

According to Merriam (1998), qualitative research seeks to understand real-world phenomena with as little disturbance of the environment as possible. She stated that the key approach on which all types of qualitative research are based is investigation of how individuals interact with the social world around them – in other words, how people make sense of their world and experiences. Qualitative research tries to understand how all facets of a scenario work together as a whole. Merriam indicated that it is important to
understand the observed phenomena from the subjects’ perspective and not from the point of view of the researcher, even though the researcher is the main tool for data collection. Further, qualitative research requires that fieldwork be done by the investigator. This means the researcher must visit the locations under study, and meet and interact with the people in question. Merriam said that another key to qualitative research is to use an inductive approach to examine various aspects of a phenomenon. She added that the research is reported in words and graphics to provide a rich description of the observations. Finally, she pointed out that sample selection is not random, but rather is highly selective because of the uniqueness of the cases to be examined.

Qualitative research is multi-modal in scope, meaning that various types of instruments are used to examine a case (Creswell, 2009; Ragin et al., 2004; Strauss and Corbin, 1998). Qualitative researchers use “thick description,” defined as in-depth written detail of the observations being analyzed (Collier et al., 2004; Merriam, 1998; Miles and Huberman, 1994). Researchers frequently spend lengthy amounts of time developing rigorous, deep levels of analysis in their cases (Ragin, 2004; Weitzman, 2004). Small numbers of cases are studied because they are complex and unique, and thus cannot be examined in large quantity (Lamont, 2004; Ragin et al., 2004). In contrast, quantitative researchers base their conclusions on “thin analysis,” which refers to breadth in observations of large populations or statistical relationships between variables in large data sets (Collier et al., 2004).

Qualitative researchers are interested in data aspects that are similar between cases, whereas quantitative researchers tend to be interested in differences between data sets (Becker, 2004). Often qualitative research is viewed as a narrative form of
examination (Miles and Huberman, 1994), while quantitative research is based on ordinal, interval, or ratio data (Collier et al., 2004). Quantitative research employs statistical analysis, whereas qualitative research usually does not (Collier et al., 2004). Quantitative researchers generally look for statistical patterns within large populations, while qualitative researchers look for similarities within and among a small number of cases (Collier et al., 2004; Ragin, 2004).

Qualitative and quantitative research can complement one another, as opposed to being seen as competing or mutually exclusive (Ragin et al., 2004). According to Blee (2004), qualitative research should be evaluated on its own merits and not be discounted in comparison to quantitative research. Lamont (2004, p. 93) further indicated that researchers can successfully be “methodologically polyvalent.” Qualitative and quantitative research methods can be combined to enhance research results (Collier et al., 2004; Cresswell, 2009; Satterfield, 2004), and the qualitative/quantitative divide can be viewed instead as a continuum (Ragin, 2004). Both thick and thin observations represent sound forms of research methods (Collier et al., 2004). According to Collier et al. (p. 73), qualitative research tends to be founded on “descriptions, concepts, categories, and interpretations.” Similarly, Merriam (1998, pp. 7-8) stated that “qualitative research findings are in the form of themes, categories, typologies, concepts, [and] tentative hypotheses.” Katz (2004) indicated that the more detailed the descriptions a qualitative researcher produces, the better the data set. Wolcott (2001) focused an entire book on how to write up these thick descriptions and interpretations.
What Is a Case Study?

Numerous definitions of the term “case study” exist. Creswell (2009, p. 13), citing Stake (1995), defined it as “a strategy of inquiry in which the researcher explores in depth a program, event, activity, process, or one or more individuals. Cases are bound by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period of time.” As defined by Yin (2003b), case studies are a method of qualitative research used when questions of “how” or “why” are being asked by an investigator. Case studies are used to examine complicated phenomena in our society, allowing researchers to develop a holistic view of the study subjects within their environmental context. Case studies embody an empirical approach to look at phenomena in their everyday environments in situations for which the phenomena and context cannot be separated from each other (Yin, 2003a; Yin, 2003b). Yin also stated that case study inquiries require many sources of data that must be triangulated to attain a fuller understanding of the events in question (Yin, 2003b).

As explained in Merriam (1998), case study methods are widely employed in education. She stated that three aspects integral to qualitative case studies are that they be particularistic, descriptive, and heuristic (pp. 29-30). Particularistic means dealing with a specific instance, event, organizational unit, or individual. Descriptive refers to thick analysis of the events under investigation. Heuristic means providing new understanding about an event or a set of events. Methods of data collection for case studies include collecting quotes from participants, video taping and analysis, conducting interviews, distributing questionnaires, and examining documents, among others (Merriam, 1998; Maxwell, 2005).
**Design of Experiment**

In this study, four high schools were chosen to participate based on the inclusion of BLV students in their mainstream science classrooms. Individual case studies were constructed for each participating school and included the collection of demographic information. To protect the identities of the participating institutions, they were given pseudonyms: Badger High School, Highland Hills High School, Rollinsville High School, and Twin Pines Academy. All teachers and students participating in this study were also given pseudonyms to protect their identities.

A detailed ILAB tool-training module was offered to each participating science teacher and BLV student prior to the 2007-08 school year. The purpose was to demonstrate how the tools worked, to collect initial feedback, and to familiarize the students with the laboratory environment. Safety concerns were also covered to minimize the risks of injury inherent in any laboratory activities. Whenever possible during these training sessions, simple experiments were set up to give the BLV students additional opportunities to try out the ILAB tools in order to further familiarize themselves with the technology and establish some level of self-efficacy. Self-efficacy was defined by Shunk (1996, p. 4) as how individuals perceive their capabilities of accomplishing a task. At the end of each module, the BLV students were encouraged to practice what they had learned to reinforce retention of the information.

The data presented in this study were collected in year one of a three-year project. Each BLV student in the study participated in numerous laboratory experiments within lab groups with sighted students. These experiments were typical to high school science classes but were slightly modified to allow inclusion of the students with BLV. Several
instruments were used to gather the case study data, including pre- and post-school-year interviews of student participants, post-school-year interviews of science teachers, pre- and post-school-year student science attitude surveys, and audiovisual recordings of BLV students’ laboratory activities. An external evaluator provided extensive assistance with qualitative and quantitative data analysis. The external evaluator was a science education graduate student under the guidance of Dr. William Carlsen from the Curriculum and Instruction Department at Pennsylvania State University.

Whenever possible, ILAB team members were present to observe data collection. Initially, all lab activities were requested to be recorded. Later the pre- and post-lab discussions were also recorded. The recording was done primarily by the teachers, but a camera person sometimes participated to more effectively collect the video data. Not all the video disks were found to be useable because of a lack of audio as a result of a malfunction with the Bluetooth microphone and also due to teacher error in using the Bluetooth; these videos were omitted from the study.

**Internal Controls**

The ILAB study required the use of an internal control for each case because it was not possible to have both an experimental group and a control group of BLV science students at each site, since having two or more BLV students in one class in a mainstream setting is very rare. Additionally, since each institution was its own isolated environment with different teachers, curricula, resources, and facilities, the schools could not be compared directly to each other in some aspects; it was not possible to control for certain variables between schools among individual participating subjects.
For the internal control, all student participants used the ILAB assistive-technology tools in 80% of the experiments and did not use them in 20% of the experiments. Prior to the school year, each laboratory experiment within each course was labeled with a number. Then a randomization process selected the numbered experiments for each school that would exclude the use of ILAB tools; this was done to eliminate researcher bias in experiment selection. ILAB tool compatibility for the laboratory experiments was not taken into account during the randomization. The videos in which BLV students did not use the ILAB tools were then compared to those in which the ILAB tools were used.

**Participant Selection**

The four student participants in this investigation were recruited through outreach activities at National Federation of the Blind (NFB) conventions in 2006 and 2007. An exhibit table where ILAB tools were demonstrated was set up to attract the attention of conference attendees. Those interested were contacted after each outreach event to determine their eligibility to participate in the ILAB study. Not all students who expressed an interest in the ILAB project were selected. Criteria included having blindness or low vision, being enrolled in a science class for the upcoming school year, and obtaining all necessary permissions. Before any ILAB project involvement could begin, consent forms were required from students, parents, teachers, and school administrators. Anyone not meeting all criteria was excluded from the study. A total of five students met all criteria; however, the teacher for one student neglected to provide
the required audiovisual recordings of participant lab activities for analysis. Therefore, four students are included in this dissertation.

Approval from the Institutional Review Board (IRB) in Pennsylvania State University’s Office of Research Protections (ORP) was also required prior to data collection. (See Appendix B for the IRB-approved student/parent/teacher consent forms.) Annual reviews by the ORP were also required.

**Data Collection Instruments**

This study employed several instruments involving qualitative and quantitative research approaches. These instruments included:

**Pre- and Post-School-Year Interviews**

Interviews of students were used as part of the ILAB study to obtain background information and qualitative commentary from each subject. Interviews are widely used as a form of qualitative data collection in investigations of educational settings (e.g., Certo et al., 2008; Chand, 2007; Donalson, 2008; Haskell and Champion, 2008; Karp and Hughes, 2008; Mukamusoni, 2006; Palincsar et al., 2001; Whiteman, 2005; Wilkins, 2008).

The questions in the ILAB interviews were originally designed by an ILAB team member for testing in a residential school for the blind, and then later modified by the investigator for use with BLV students in mainstream schools. These questions were directly related to the ILAB causal map illustrated in Figure 1-1 in Chapter 1. Some of the areas of inquiry were students’ interest in science and STEM careers, how they felt
they worked with sighted peers in groups, their contributions to tasks related to the completion of lab goals, their involvement with the hands-on aspects of the laboratory experiences, and their use of ILAB tools. Based on initial responses, some questions were followed up with clarification inquiries by the interviewer.

The pre-school-year student interviews were administered after the preliminary ILAB training sessions but prior to commencement of the coursework, and included questions regarding visual acuity and ability to perceive colors. The text of the pre-school-year interview questions appears in Table 4-1. The post-school-year student interviews were administered after completion of the coursework and were intended to obtain follow-up information regarding how the course had gone for each participant. The goal was to obtain feedback on students’ feelings toward science, how the ILAB tools had been useful or detrimental in the laboratory classes, and the quality of student interactions within lab groups. The post-school-year interview questions are listed in Table 4-2.

Post-school-year teacher interviews were also conducted to obtain observational feedback from the teachers regarding the students with BLV and their interactions within classrooms and lab groups during laboratory lessons. The text of the teacher interview questions appears in Table 4-3.

All interviews were digitally audio-recorded and transcribed verbatim with no corrections for grammar. “[Inaudible]” was indicated when dialogue was not understandable. Interview transcripts were then examined to determine the most significant questions. Excerpts from the responses to these questions are quoted in the case studies (Chapters 6-9).
### Table 4-1: Pre-School-Year Student Interview Questions

Following is the text of the pre-school-year interview questions that were administered to participating students:

1. Please describe your visual acuity. What are you able to see? How far? How small?
2. How well are you able to perceive colors?
3. What would you like to do for a career after you’re finished with your education?
4. Have you been in any mainstream science courses?
5. What other science courses have you taken?
6. What do you plan on majoring in at college?
7. Can you describe for me how you experienced and participated in a science lab class before?
8. How do you feel about working with sighted students in your class to conduct experiments?
9. Do you have any apprehension or excitement toward your upcoming laboratory class experience?
10. How familiar are you with the ILAB tool functionality?
11. Do you think more training would assist you in the use of these tools?

### Table 4-2: Post-School-Year Student Interview Questions

Following is the text of the post-school-year interview questions that were administered to participating students:

1. How did the laboratory class go for you this year?
2. What was your favorite part of the class?
3. What was your least favorite part of the class?
4. Did you like the laboratory part?
5. Did you have a favorite aspect about the laboratory portion of the class?
6. What was your least favorite aspect about the laboratory portion of the class?
7. Do you think that if you had adaptive tools in the future, they would help you do things on your own in the lab?
8. Did the labs help you understand what Mr./Ms. [teacher name] was teaching?
9. Can you describe some of the techniques you used in lab?
Table 4-2 continued

10. As the year went on, did working in the lab become easier?
11. How much help did you get from Mr./Ms. [teacher name]?
12. What would make experiments easier for you to run?
13. Do you think your visual impairment makes working in the lab difficult?
14. In addition to the tools you were able to use this school year, are there any other tools you would like to see developed to help you in the lab?
15. Was it difficult for you to tell when certain things happened during an experiment, and, if so, what were some of them?
16. When you were working as part of a team, did you tend to work on the things easiest for you to do?
17. Did it seem that the people who took on other parts of the experiment were able to do them well, or did some people find themselves unable to do certain tasks?
18. How were tasks and lab partners determined for each experiment?
19. Do you think this class helped you to realize that you could do science, and that it wouldn't be too hard for you even if you didn't necessarily like the course material?
20. Many activities in class called for observation. What ways did you use to observe?
21. Do you feel these other ways of observing worked well?
22. Which senses did you feel were most important to use in class?
23. Do you think this class helped or hindered your desire to be a scientist?
24. As of right now, what do you want, or are planning, for a career?
25. Overall, how was this year’s class?
Table 4-3: Post-School-Year Teacher Interview Questions

Following is the text of the post-school-year interview questions that were administered to participating teachers:

1. How has the year gone?
2. Was this year's group pretty typical of those you've had in previous years?
3. What was the easiest part of the year, from a teacher's perspective?
4. What was the hardest part of the year?
5. What do you think was the favorite lab of your blind student?
6. What was the blind student's least favorite lab, from your perspective?
7. From your perspective, which lab was the easiest for the blind student, for which he/she had the least amount of problems performing the tasks and techniques?
8. Which lab was the hardest for the blind student to run, and why?
9. Within the lab groups, did each student remain in his/her comfort zone? If yes, was each team able to perform the experiment?
10. Were there any specific techniques with any of the labs that didn't require modification?
11. What techniques that you adapted for your blind student did you find were the easiest for him/her to do?
12. What techniques that you adapted were the hardest for him/her to use in lab?
13. How well do you think the blind student was able to use the ILAB tools to participate in the lab groups?
14. What do you think his/her lab group partners' feelings were toward the blind student's use of the ILAB tools?
15. Did you notice an increase in the student's self-efficacy or confidence throughout this school year in the labs?
16. How much help did you personally give the students, blind or sighted?
17. Can you describe a typical laboratory period?
18. From your perspective, how well did the blind student work with the other students, since the labs are done in groups?
19. From your perspective, what would make running the labs easier?
20. Based on this teaching experience, how did your blind student's visual impairment impact him/her in the lab?
21. What other tools would you like to see developed for your labs?
Scientific Attitude Inventory II (SAI II)

The SAI II (Moore and Foy, 1997) was administered to each student participant pre- and post-school year to measure how the ILAB experience impacted their attitudes toward science. (While the data contained in this dissertation were from the first year of a three-year project, students who participated for more than one year were readministered the SAI II at the conclusion of the second year.) The SAI II measures opinions within six attitudinal constructs considered by Moore, the author of the instrument, to be particularly important in determining attitudes about science. These constructs deal with:

1. Whether the laws and theories of science evolve over time as new information becomes known.
2. Whether science can answer all questions about all phenomena.
3. Whether scientists should always be willing to honestly report objective observations and alter their views based on new evidence.
4. Whether the primary purpose of science is to seek explanatory evidence for natural phenomena or to focus on developing practical technologies.
5. Whether the general public is capable of understanding science and should support the quest for scientific knowledge.
6. Whether science would be a desirable career path.

Each attitudinal construct includes matched pairs of questions written from a positive and a negative slant but not generally appearing next to each other. The first five constructs have six questions each, and the sixth construct has 10 questions, totaling 40 queries for the survey. Twenty of the questions are positive and 20 are negative, with some of the questions being very similar to others to gauge the consistency of responses.
All questions are intended to be answered on a five-point Likert scale, with “strongly agree” and “strongly disagree” for the positive-slanted questions having point values of 5 and 1, respectively. Point values for the negative-slanted questions are reverse-coded; that is, 1 indicates “strongly agree” and 5 indicates “strongly disagree.” Therefore, high totals both for positive and negative questions indicate a good attitude toward science. A point value of 3 indicates “neutral/undecided” both for positive- and negative-slanted items. The remaining intermediate options are “mildly agree” and “mildly disagree,” coded as either 4 or 2 depending on whether an item’s slant is positive or negative (Moore and Foy, 1997). For the positive and negative questions totaled separately, a score of 100 would indicate complete positivity in attitude, while 20 would indicate complete negativity. For the positive and negative questions totaled together, a perfect score is 200, the worst is 40, and neutral/undecided is 120.

For purposes of analysis, the positive questions are categorized as “A” and negative questions are categorized as “B.” The A and B categorizations are not indicated within the survey itself as given to participating subjects (Moore and Foy, 1997). In this study, all SAI II question scores were tallied and recorded in Microsoft Excel spreadsheets. The results appear in Chapters 6-9. See Table 4-4 for the text of the SAI II questions as they were administered to ILAB study participants.

The SAI II survey was selected for its wide range of applications in the six attitudinal constructs, along with its relative brevity and user friendliness for participants. Moore and Foy (1997) developed the SAI II survey as a revision of Moore’s original SAI designed in the early 1970s. They administered the SAI II to 557 students in grades six, nine, and twelve – an age group roughly equivalent to that in the ILAB project. They
obtained a Spearman Brown split-half reliability coefficient of 0.805, along with a Cronbach’s alpha reliability coefficient of 0.781. These statistical reliabilities indicate strong correlations between the six attitudinal constructs. Moore and Foy’s published data set served as a comparison of instrument efficacy for the ILAB data.

Table 4-4: The 40 Questions of the Scientific Attitude Inventory II as Administered to ILAB Study Participants

Please respond to each statement and blacken only ONE space for each statement.

1. I would enjoy studying science.
2. Anything we need to know can be found out through science.
3. It is useless to listen to a new idea unless everybody agrees with it.
4. Scientists are always interested in better explanations of things.
5. If one scientist says an idea is true, all other scientists will believe it.
6. Only highly trained scientists can understand science.
7. We can always get answers to our questions by asking a scientist.
8. Most people are not able to understand science.
9. Electronics are examples of the really valuable products of science.
10. Scientists cannot always find the answers to their questions.
11. When scientists have a good explanation, they do not try to make it better.
12. Most people can understand science.
13. The search for scientific knowledge would be boring.
14. Scientific work would be too hard for me.
15. Scientists discover laws which tell us exactly what is going on in nature.
16. Scientific ideas can be changed.
17. Scientific questions are answered by observing things.
18. Good scientists are willing to change their ideas.
19. Some questions cannot be answered by science.
20. A scientist must have a good imagination to create new ideas.
21. Ideas are the important result of science.
22. I do not want to be a scientist.
23. People must understand science because it affects their lives.
Table 4-4 continued

24. A major purpose of science is to produce new drugs and save lives.
25. Scientists must report exactly what they observe.
26. If a scientist cannot answer a question, another scientist can.
27. I would like to work with other scientists to solve scientific problems.
28. Science tries to explain how things happen.
29. Every citizen should understand science.
30. I may not make great discoveries, but working in science would be fun.
31. A major purpose of science is to help people live better.
32. Scientists should not criticize each other’s work.
33. The senses are one of the most important tools a scientist has.
34. Scientists believe that nothing is known to be true for sure.
35. Scientific laws have been proven beyond all possible doubt.
36. I would like to be a scientist.
37. Scientists do not have enough time for their families or for fun.
38. Scientific work is useful only to scientists.
39. Scientists have to study too much.
40. Working in a science laboratory would be fun.

Audiovisual Recordings

During in-class experiments, all laboratory activities of the participating students were video- and audio-recorded onsite. Videos from each participating school were recorded by teachers using Sony Handicams mounted on tripods and interfaced with Bluetooth microphones. Camera locations were determined by teachers and ILAB team members. All audio was recorded through the use of Bluetooth microphones, originally placed in the workspace of the BLV students’ lab groups, and later worn by the BLV students. All footage was placed onto mini DVD-R disks and returned to the investigator. DVDs were labeled and categorized by school and year, and stored in a safe.
The videos were copied onto laptop computers and converted into Audio Video Interleave (AVI), a Microsoft multimedia container format. The videos were then imported into the NVivo video analysis software package from QSR International in Melbourne, Australia. NVivo is a powerful tool that has been widely used by other researchers (e.g., Chand, 2007; Donalson, 2008; Karp and Hughes, 2008; Mukamusoni, 2006; Whiteman, 2005). Two videos incorporating ILAB tool use (I-videos) and two videos not incorporating ILAB tools (N-videos) from each school were selected for analysis. Later, a third ILAB tool video was included for additional data points, making a total of five videos from each school. In general, criteria for video selection were the quality of the audio and video coverage and, for the I-videos, the quality of tool implementation. However, the number of videos submitted was highly variable from school to school, and those submitting a small number of videos substantially limited the selection possibilities.

The videos were then transcribed and encoded in the NVivo software by a team of undergraduate students. All audible dialogue was transcribed verbatim with no corrections for grammar, in order to maintain accurate records of what was said during the lessons. When dialogue was not understandable, the term “[inaudible]” was used.

All discernable and intelligible actions and utterances made both by BLV students and their sighted lab partners while using any laboratory equipment, including but not limited to ILAB tools, were noted in the transcriptions. Sighted students in lab groups with BLV students were permitted to use the ILAB tools. All these actions and utterances were time stamped and described with the use of NVivo. The transcripts were then exported into Microsoft Word files for further investigation, including video task analysis.
and statistical analysis of the video data presented in graphical form. Additionally conducted on the videos themselves was rubric analysis of the video data.

**Video Task Analysis**

In the video task analysis, which was performed on revealing excerpts from the transcripts, actions performed by the student with BLV (as noted within the transcript excerpts) were listed, described, and categorized as either involving or not involving ILAB tools, and the context of the actions was examined. Not all actions in the video task analysis were necessarily directed toward laboratory goals and in some cases included setup, clean up, waiting, taking notes, and making calculations.

**Graphic Analysis of Video Data**

In contrast, for the statistical analysis of actions recorded in the video data and noted in the transcripts, the results of which are displayed in bar graphs in Chapters 6-10, actions were required to meet specific criteria and were more strictly defined and categorized. Actions were defined as physical tasks noted in each transcript that were directly related to achieving laboratory goals. Manipulating equipment to perform experiments and taking data points were among the activities defined as actions. Not counted as actions were activities such as listening to lecture, reading laboratory procedures, waiting to use equipment or for reactions to occur, taking notes, making calculations, setting up the equipment, and cleaning up.

As with the video task analysis, the actions were broken down into I-tasks (those using ILAB tools) and N-tasks (those not using ILAB tools), because not all tasks in the
I-videos required the use of ILAB tools. Then the percent of time engaged (PTE) in laboratory-goal-directed actions was calculated for the BLV student and his/her sighted lab partner(s) in each video. The PTE included the engagement time of I-tasks and N-tasks together, to see if the overall PTE of each BLV student was affected by the presence or absence of ILAB tools. The PTE for the BLV student in each video was also compared to that of his or her sighted lab group partner(s). In this comparison, only the sighted student(s) who contributed the most PTE were included.

To arrive at the PTE, time spent on laboratory-goal-directed actions was totaled for the BLV student and for the sighted student(s). These two amounts were then summed; the BLV student’s total time spent on actions was divided by this sum and multiplied by 100 to get a relative percentage. The relative percentage for the sighted student(s) was calculated in the same manner. Bar graphs were constructed for each laboratory lesson, graphically comparing PTE between each BLV student and his/her sighted lab partner(s). The N-tool lessons were also compared to the I-tool lessons within each case for BLV and sighted. The PTEs for individual lessons are presented in bar-graph form within the case study chapters. An overall set of bar graphs was also constructed, illustrating the data for all four schools, as can be seen in Chapter 10.

In addition to time expended by the BLV students and his/her lab partners on laboratory-goal-directed actions involving I-tasks and N-tasks, the total time expended by each pertinent student on other categories of activities was tabulated and calculated for each video transcript. These categories included reading lab procedures, waiting, taking notes or performing calculations, actions and utterances involving setup, actions and utterances involving clean up, and actions and utterances completely unrelated to the
laboratory lesson. Also tabulated and calculated was all time spent by the teacher on lecturing, making comments, and performing actions; and all time spent on actions and utterances by other people in the classroom, such as teacher’s aides or classmates who were not part of the BLV students’ lab groups. The PTE for laboratory-goal-directed actions was deemed to be the most pertinent data for graphical analysis for the purposes of this study, since the object of the ILAB intervention was to increase the hands-on participation of the BLV students. However, a summary of the results of the entire tabulation of the video transcript data can be requested from the investigator.

**Rubric Analysis of Video Data**

A rubric was constructed by ILAB team members for use by the investigator, external evaluator, and independent rater, who each applied it to every video in the ILAB data set. The external evaluator was a Pennsylvania State University graduate student in science education, and the independent rater was a graduate student in special education at Purdue University. The independent rater supplied outside validation of the rubric results separate from that of the investigator and external evaluator.

The purpose of the rubric was to collect information from the videos regarding how much the BLV students contributed to their lab groups and the levels of acceptance of the BLV students into their lab groups during laboratory lessons, including those with without the use of ILAB tools. The rubric consisted of a series of yes/no and Likert-scale questions that each rater answered individually based on their interpretations of what they observed in the videos and video transcripts. All videos and transcripts in the data set were viewed and coded separately by the three raters. The results appear in Chapters 6-9.
Fleiss’ Kappa coefficients for inter-rater reliability were determined for each question in the video analysis rubric; these results appear in Chapter 10. (Fleiss’ Kappa coefficient is a statistical means of determining the reliability of agreement between multiple raters who divide ratings into various categories.) Also in Chapter 10 is a detailed comparison of rubric results for the BLV students as a group.

The text of the rubric appears in Table 4-5.
**Table 4-5: Video Analysis Rubric Used by Investigator, External Evaluator, and Independent Rater for Each Video in Data Set**

**ILAB Video Analysis Rubric**

| School Name: | ________________________________________________________________________________________________ |
| Title of Video: | ________________________________________________________________________________________________ |
| Rater Name: | ________________________________________________________________________________________________ |
| Dates and Times of Rating: | ________________________________________________________________________________________________ |

**A. The student with BLV is significantly involved in discussions relating to the completion of the laboratory goal.**

**Yes:**

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

**No:**

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Only rate statements that are of at least four seconds in duration. A statement relevant to completion of the lab goal should be considered significant, as opposed to a statement that is off-task. For example, if a statement gives an explanation of some aspect of the lab goal, that would be counted as “yes.” If the statement is a question or series of questions regarding the completion of the lab goal, that also would be a “yes.” (According to the scientific method, asking questions is regarded as significant, even if the questions are leading down the wrong path. We are not grading accuracy of content, but rather whether or not the dialogue is directed toward completion of the lab goal.)
Table 4-5 continued

B. Sighted students fully accept the contributions of the student with BLV.

Yes:

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

No:

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

When you watch the video and review the transcript, you will be able to note how the sighted students respond to comments by the student with BLV. You should count the number of contributions that were accepted by the sighted students and the number of contributions that were not accepted. Examples: If a student with BLV suggests a course of action, and the group accepts it and implements it, count that as “yes.” If the student with BLV never makes a suggestion on a course of action, count that as “no.” If the student with BLV makes a suggestion and the group does not accept it, that also is “no.” We are not rating the accuracy of stated contributions, but only whether the group listened and took a specific course of action based on suggestions by the student with BLV.
Table 4-5 continued

C. Does the student with BLV express interest in the science experiment?

View the entire video and read the entire transcript, then note the changes in level of interest exhibited by the student with BLV during the experiment. Great interest can be illustrated by a raised voice, smiling throughout, engaging in lengthy dialogue or questions and answers, and a higher level of physical involvement in performing tasks.

“Strongly agree” would indicate a high level of interest by the student.

“Agree” would mean there was a noticeable amount of interest.

“No opinion” would indicate the rater could not tell whether the student was interested or not.

“Disagree” would mean there were some aspects that appeared to lower the level of interest to the point of possible negativity. This could be due to the lab group not accepting the suggestions of the student with BLV, or the student with BLV simply not being prepared for the experiment.

“Strongly disagree” would indicate an almost antagonistic attitude. Most aspects of the involvement of the student with BLV in the lab were negative and not valued by the group.

(1)       (2)        (3)      (4)               (5)       
Strongly Disagree Disagree No Opinion      Agree       Strongly Agree

The student with BLV expresses high overall interest in the science experiment:  
___________________

The level of interest of the student with BLV stayed the same throughout the experiment:  
___________________

The level of interest exhibited by the student with BLV increased during the experiment as a result of comprehending the material:  
___________________

The level of interest exhibited by the BLV student decreased during the experiment due to losing interest in the activity:  
___________________
Table 4-5 continued

D. The techniques employed by the student with BLV were perceived by the sighted members of the laboratory group as beneficial:

<table>
<thead>
<tr>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>No Opinion</td>
<td>Agree</td>
<td>Strongly Agree</td>
</tr>
</tbody>
</table>

View the entire video and read the entire transcript, then note the overall attitude of the sighted group members toward the tasks performed by the student with BLV regarding completion of the lab, whether or not ILAB tools were present.

“Strongly agree” correlates to high levels of attention being exhibited by sighted group members toward what the student with BLV says. This attention may be apparent through a good deal of positive verbal responses, nodding, and smiling by sighted group members. The sighted group members are supportive of the tasks suggested by the student with BLV and may assist with the tasks.

“Agree” would indicate some nodding and smiling with regard to statements made by the student with BLV, but also some level of non-committal comments such as “OK, whatever you say.” The sighted group members are somewhat supportive of the tasks suggested by the student with BLV.

“No opinion” would mean it is difficult to determine if feedback from sighted students toward statements by the student with BLV are positive or negative. There is very little nodding, smiling, or supportive statements or behavior.

“Disagree” would indicate the sighted students are not giving the student with BLV their full attention, and in some instances respond with grimaces, glares, and with performing other aspects of the experiment while the student with BLV is talking.

“Strongly disagree” would mean that little, if any, respect is given to the student with BLV. There are many grimaces/glares toward the student with BLV, with very little other attention being paid to him/her.
Table 4-5 continued

E. Was the student with BLV included in the collaborative participation of the group?

Circle one: Yes No

Do not answer this question until you have viewed the entire video and read the entire transcript. Your focus will be on rating whether the group included the student with BLV in their collaborative tasks versus excluding the student with BLV from the synergy between the group members.

“Yes” would indicate that over 50% of the actions viewed in the video were performed in a manner inclusive and collaborative with the BLV student. Examples: One person may perform a task under the guidance or encouragement of the other group members including the student with BLV. Or multiple members of the group may assist each other with performing aspects of the experiment, including setup, clean up, and the experiment itself. Or the student with BLV contributes substantial amounts of useful discussion toward completion of the experiment. Or, if the student with BLV is perceived to have low comprehension of the tasks, other group members and/or the teacher explains aspects of the experiment, and subsequent statements and actions from the student with BLV indicate increased comprehension.

“No” would mean that less than 50% of the video footage illustrates the types of collaborative behavior illustrated above. Non-collaboration is represented by the student with BLV not participating in large portions of the discussions, setup, clean up, and/or performing of the experiment.

F. Additional comments or unforeseen occurrences worth noting:

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
Qualitative and Quantitative Case Study Analysis

One case study was constructed for each participating school. Demographic data were collected for each, and information regarding the ability of each student with low vision to see color and their overall visual acuity was gathered. The goal of collecting all this information was to construct a complete picture of the environmental circumstances under which each BLV student participated.

Data gathered through the case study instruments (pre- and post-school-year interviews of student participants, post-school-year science teacher interviews, pre- and post-school-year student attitude surveys, audiovisual recordings and transcripts of participating BLV students’ laboratory activities, and the video analysis rubric) were triangulated to highlight mutually confirmatory evidence. Triangulation entails the use of multiple sources of information (Maxwell, 2005; Wolcott, 2001; Yin, 2003b). Using multiple sources of information is more important in case study research than in other types of investigations and is considered a major strength of case study research design (Yin, 2003b, p. 97; Wolcott, 2001, p. 30). As stated by Yin (p. 98), “[T]he most important advantage presented by using multiple sources of evidence is the development of converging lines of inquiry” (italics are in the original). Maxwell (p. 93) stated that this approach reduces the influences of potential sources of bias or limitations of any one research instrument.

Each case study in this dissertation contains the following sections: introduction; demographics of school; background of student; background of teacher; classroom resources; relationship between investigator, teacher, BLV student, and parents; interview data; SAI II data; overview of the laboratory lessons; video task analysis; graphic
analysis of video data; video analysis rubric results; and summary. The students’ eventual familiarity with ILAB tools was also factored into each case study. The data collected for each case was separated into individual tables and graphs in Chapters 6-9 and also compared across cases in Chapter 10. Investigator commentary regarding the analyses is also included, based on field experiences, collected data, and findings.

Statistical methodologies such as paired sample t-tests, permutation tests, a Bonferroni correction, and Fleiss’ Kappa coefficients were used along with qualitative description and commentary. Within individual case studies, variations in lab partners from lesson to lesson introduced variability that was not easily quantifiable and thus contributed to random error.

It was the intent of the investigator that the case studies richly tell the stories of participating students Nate, Ryan, Neil, and Emily, and to document how their experiences with the ILAB tools may have impacted their science learning and attitudes toward science. Key points unique to each case are noted in the summary sections of Chapters 6-9. The variables examined in the case studies and their descriptions are listed in Table 4-6.
Table 4-6: Variables and Their Descriptions

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-Time</td>
<td>Percent of time each BLV and sighted student contributed to the completion of each lesson using non-ILAB tools</td>
<td>Continuous</td>
</tr>
<tr>
<td>I-Time</td>
<td>Percent of time each BLV and sighted student contributed to the completion of each lesson using ILAB tools</td>
<td>Continuous</td>
</tr>
<tr>
<td>School</td>
<td>High school involved in analyses; 4 schools</td>
<td>Discrete</td>
</tr>
<tr>
<td>Student</td>
<td>BLV student involved in analyses; 1 per school</td>
<td>Discrete</td>
</tr>
<tr>
<td>Teacher/Class/Curriculum</td>
<td>Teacher, science class, and curriculum being taught for each participating student at each of the 4 schools</td>
<td>Discrete</td>
</tr>
<tr>
<td>Lesson</td>
<td>Science class lab activities for which data were collected; 5 lessons nested within each school</td>
<td>Discrete</td>
</tr>
<tr>
<td>Tool</td>
<td>Indicator as to whether ILAB tools were available for a particular lesson; 2 levels: yes if ILAB tools available, no if ILAB tools not available</td>
<td>Discrete</td>
</tr>
<tr>
<td>Percent of Time Engaged (PTE)</td>
<td>Relative percent of time each BLV student and sighted student contributed to completion of each lesson; includes both N-time and I-time</td>
<td>Continuous</td>
</tr>
<tr>
<td>Pre1 - Pre6</td>
<td>1AB - 6AB attitudinal construct subscores for each BLV student on SAI II survey taken prior to academic year (AB indicates the subscores for positive and negative items)</td>
<td>Continuous</td>
</tr>
<tr>
<td>Post1 - Post6</td>
<td>1AB - 6AB attitudinal construct subscores for each BLV student on SAI II survey taken after academic year</td>
<td>Continuous</td>
</tr>
<tr>
<td>Rubric Question A</td>
<td>Answer for question A from Video Analysis Rubric for each of 3 raters; 2 levels: 0, 1</td>
<td>Discrete</td>
</tr>
<tr>
<td>Rubric Question B</td>
<td>Answer for question B from Video Analysis Rubric for each of 3 raters; 2 levels: 0, 1</td>
<td>Discrete</td>
</tr>
<tr>
<td>Rubric Questions C1 - C4</td>
<td>Answers for questions C1 - C4 from Video Analysis Rubric for each of 3 raters; 5 levels: 1, 2, 3, 4, 5</td>
<td>Continuous</td>
</tr>
<tr>
<td>Rubric Question D</td>
<td>Answer for question D from Video Analysis Rubric for each of 3 raters; 5 levels: 1, 2, 3, 4, 5</td>
<td>Continuous</td>
</tr>
<tr>
<td>Rubric Question E</td>
<td>Answer for question E from Video Analysis Rubric for each of 3 raters; 2 levels: 0, 1</td>
<td>Discrete</td>
</tr>
<tr>
<td>Rubric Question F</td>
<td>Answer for question F from Video Analysis Rubric for each of 3 raters; open-ended</td>
<td>Qualitative</td>
</tr>
</tbody>
</table>

Source: Adapted from Johnson and Fu (2010)
The cross-case analysis in Chapter 10 was conducted to identify commonalities among the four case studies. While there are multiple methods of conducting cross-case analyses, for the purposes of the ILAB study the data points within each case were compared not just with one another for triangulation within cases but also were compared across all four cases. The use of multiple cases adds robustness to qualitative research findings and allows the investigator to avoid possible criticisms that could arise when using only one case (Yin, 2003a, p. 135). In cross-case analysis, each case study is regarded as an isolated investigation, and then findings from each are compared among cases (Yin, 2003b, p. 134).

Miles and Huberman (1994, pp. 172-173) stated that many researchers use multiple-case, or cross-case, analysis. One goal is to increase the generalizability of the findings to wider populations than those specifically studied in the cases. The expectation is to observe trends across multiple cases in an attempt to draw conclusions on the phenomenon being studied and also to deepen understanding of the phenomenon. All cases to be examined through cross-case analysis should be structured in a similar fashion to aid in synthesizing interpretations across the multiple cases.

However, when conducting a cross-case analysis, while the environment for each case is different from the others, certain key elements are similar, so that common themes and patterns can be observed. In the ILAB study, the schools, teachers, and participating students were all different; the use of ILAB tools, mainstream science classes, and BLV students were the common elements.
Potential Confounding Factors

The investigator recognizes that since he is totally blind, the potential for bias toward desired outcomes may pose a concern. Such concern could involve participant selection, questions asked in interviews, and selective inclusion of analyses and descriptions supportive of the hypotheses of this investigation. However, to minimize possible bias and so that readers may draw their own conclusions, the investigator has included within each case study chapter numerous substantial excerpts, both positive and negative, taken from the transcripts of interviews and videos.

Other factors that may have impacted the outcomes of this investigation include participating students’ amount of usable vision (if any), their oral communication skills, and their familiarity with access technologies. The presence or absence of residual vision affected the ability of some students to participate in labs both with and without ILAB tools, in that some students could conduct experiments using their sight to complement their hands-on participation, while others could not. Residual sight may have allowed low-vision students to perform tasks they might not otherwise have been able to perform.

Students’ ability to articulate questions and communicate with their group partners varied from person to person. Comfort with using existing access technologies, basic computer skills, and familiarity with Windows and the JAWS text-to-speech screen-reader application also impacted students’ efficacy with the ILAB tools. The amount of physical resources in classrooms – such as computers, glassware, and workstations – impacted lab group size, thus affecting the number of tasks performed by each student. Specific curricula and the inherent ability of the students to comprehend the subject matter also had an effect on their lab participation and level of interest in science.
Chapter 5

ILAB Tools: Development and Utility

According to Ashcroft (1991, p. 10), the availability of computer-based assistive technologies is one of “the most significant developments in communications skills for students with visual handicaps in the 150 years since Louis Braille introduced his system.” These technologies are vital for BLV students to have a more hands-on science learning experience. Assistive technologies are intended to empower persons with disabilities to access informational resources that otherwise might have been inaccessible to them due to their physical limitations. The ILAB tools and techniques were designed to bring the benefits of assistive technologies into science laboratories.

Computer Interfaces in the Science Laboratory Classroom

The following are examples of how computer interfaces have successfully been used in science laboratory classrooms, including the interfacing of computers with probes to perform data collection. The use of Vernier Software & Technology’s probeware in the classroom is also discussed in conjunction with their Data Logger software and Logger Pro data collection software package (which evolved from Data Logger). The scholarly works mentioned herein illustrate specific applications for these tools, but do not represent large-scale studies on the efficacy of the technologies and how these technologies may contribute to learning.

Thornton and Sokoloff (1990) reported on a 1987-88 study that involved physics courses at the University of Oregon and Tufts University. Both institutions utilized their first-semester physics mechanics courses, both with and without a laboratory component,
and with and without calculus. The use of a microcomputer-based laboratory (MBL) was introduced in each course. The MBL included external devices, such as motion sensors, velocity probes, and accelerometers, which could be manipulated by students and were interfaced with Apple IIe, Apple II Plus, or Apple IIGS desktop computers. Data collection software allowed the students to plot graphs and manipulate specific data points within tables.

Students were given pre- and post-tests on kinematics concepts to determine how effectively the MBL had contributed to their learning processes. The results for the courses with laboratory components and those without were compared, as well as the results for those with and without calculus. The results were similar from the two institutions, and indicated that the use of the MBL had assisted the learning processes of the students who took the laboratory components: The errors made on exams were fewer and less significant for these students as compared to those who had taken the lecture-only courses. The errors of the students who had not experienced the laboratory component were much wider in range, indicating these students generally had not learned as much about kinematics as did the students enrolled in the lecture-plus-laboratory courses. These results held true both in the calculus and non-calculus-based sections. Therefore, Thornton and Sokoloff’s study demonstrated that computer data collection software and hardware, when used to teach motion concepts in a laboratory component of a physics course at the post-secondary level, could contribute to student learning. Hands-on laboratory experiences (as described in depth in Chapter 3) may also have been contributing factors in this study.
Hart (2000) discussed a physics, electricity, and magnetism experiment using Vernier Software & Technology’s Data Logger software package in conjunction with two amplifiers, along with a resistor and capacitor to measure voltage changes during the charging and discharging of the capacitor. The students used a D-cell battery as the power source and controlled the voltage with a standard switch to complete the circuit. A separate Radio Shack digital multimeter was used to measure the voltages. The Data Logger software, along with the other equipment, was found to be easy to use by students.

In describing an experiment to test the pH of soft drinks, Christmann and Holy (2005) discussed how a Vernier pH probe could be interfaced with a TI-73/83/84 calculator using the CBL LabPro device. The authors chose this topic because soft drinks are easily relatable to middle school and high school children. They stated that while traditional pH paper could be used to measure acidity and alkalinity by observing the red or blue color change, they desired a more precise measurement. The article described how to calibrate the pH probe and take care of the probe between measurements. The authors used the Logger Pro data collection software package and either a Macintosh or PC computer. This work demonstrated how easy the Vernier probeware was to use in an experiment that was age-appropriate both for middle school and high school students.

Hoag (2005) interfaced a Durrum model 110 stopped-flow apparatus with Vernier Software & Technology’s LabPro device and the Logger Pro data collection software package to measure voltage differences in an iron(III)-thiocyanate reaction. He also used two Vernier voltage probes and a pH probe, and interfaced them with the LabPro and the Logger Pro software. Logger Pro was set to collect 50,000 data points per second. The
equilibrium constants determined experimentally in this work were found to be very similar to those of constants in earlier published works.

Bopegedera (2007) outlined a gas-laws experiment for undergraduate general chemistry laboratory courses. Students used the Logger Pro data collection software along with a Vernier gas-pressure sensor and standard pieces of glassware such as syringes and flasks of various volumes. The students used Logger Pro to graph their data and exported the data files into Microsoft Excel for further statistical manipulations. Bopegedera’s experiment illustrated various key principles of gas-pressure relationships. Gases such as CO₂, He, and N₂ were used and compared. The author found that this experiment nicely demonstrated the gas laws and made them easier to understand by students, as the laws no longer were complicated and confusing principles to memorize from textbooks, but instead were easily remembered as a result of the first-hand observations made during the experiment. This investigation became a key component of the course curriculum at Evergreen State College and was used in subsequent years.

**Evolution of the ILAB Tools**

A series of software and hardware tools were developed for use in the Independent Laboratory Access for the Blind (ILAB) project. During the early planning stages, it was determined that a suite of tools already commercially available would be utilized as the initial basis for this project. The ILAB team acknowledged that these tools could not provide total access to all laboratory experimentation but would serve as a good foundation for other tools developed at later stages.
The Vernier Software & Technology line of probeware was selected as a result of contact with company president David Vernier and his willingness to provide hardware to the ILAB team at a discount, as well as free software support. The Vernier Logger Pro data collection software was interfaced with the Job Access with Speech (JAWS) text-to-speech screen-reader software. JAWS was selected as the screen reader of choice due to its advantage of allowing customization by means of JAWS script files specially written by a computer programmer to achieve the interface with Logger Pro (Supalo et al., 2007). In 2009 the Window-Eyes text-to-speech screen-reader program (available from GW Micro) likewise developed a scripting language that may eventually allow a Window-Eyes/Logger Pro interface, but this has not yet been achieved.

The ILAB team developed various tools and initially field tested them at a Midwestern residential school for the blind, using a portion of the first NSF Research in Disabilities Education (RDE) funding for ILAB, awarded for 2004-07. During the second half of this phase, the investigator was contacted by a science teacher from a mainstream school on the East Coast, who requested ILAB tools for her blind student in a chemistry class. This action launched the first mainstream high school application of the ILAB technologies. In conjunction with the teacher’s willingness to develop a number of low-cost tools for teaching scientific concepts to students with BLV, this effort led to a long-term collaboration between the teacher and the ILAB team, and laid the groundwork for the 2007-10 ILAB grant proposal to NSF requesting funding for extending the ILAB study to mainstream high schools. The project later expanded to include 11 mainstream high school science classrooms across the United States, with curricula in general chemistry, AP chemistry, physics, AP physics, and biology. Of these 11 schools, the four
that joined the program in year one of the ILAB mainstream project comprise the case studies described in Chapters 6-9.

**Commercially Available High-Tech Tools**

Vernier Software & Technology probeware consists of an entire catalog of probes for mainstream use in general science, physics, chemistry, biology, earth science, and other scientific disciplines. Those for chemistry include conductivity probes, colorimeters, oxygen detectors, pH meters, and many others. Those in the physics package include tools for measuring magnetic fields, force, acceleration, and sound, along with photogates and more. All these probes proved useful within the varying curricula in the mainstream classrooms in the ILAB study.

Probes in the Vernier chemistry package are supplemented by a series of Ohaus balances that interface with the probes via USB connections. The Ohaus Scout Pro balance provides a wide range of functionality in measuring mass to an accuracy of 0.01g, which is sufficient for high school classroom applications. Several research-grade balances also available from Vernier have been tested with the JAWS interface and found to be accessible by blind scientists.

In general, due to the specialized nature of assistive technologies, costs associated with them tend to be high and thus are prohibitive for many blind persons. As a result, the purchase of assistive tools is typically left up to school districts, colleges/universities, and government agencies, but not all can afford them. In contrast, Vernier has worked with the ILAB team to keep its BLV-accessible products as reasonably priced as possible, making its probes cost effective for students and schools at almost all economic levels.
The diverse functionality and affordability of the Vernier probe line help provide greater access for BLV students in science classrooms when the probes are interfaced with JAWS.

Among other commercial technologies identified as useful by the ILAB project is the ID Mate II barcode reader available from Envision America. This hand-held device verbally announces information about items with barcodes when the codes are scanned. This tool was found useful in marking chemical vials and containers in the laboratory. It also provides for customization of barcodes not in its software database, thus allowing teachers to encode chemical information and materials data safety sheets for audible access by BLV students.

Another commercially available tool utilized early in the ILAB project was the Mobile Speak software package employed in conjunction with a cellular phone digital camera. Chemical reactions in solutions are often indicated by color changes, so a tool needed to be identified that could assist in the recognition of color through glass. This software had an additional plug-in available that allowed BLV students to use the digital camera as a color identifier – a very important step in an accessible chemistry laboratory curriculum. This package was selected over many other commercially available color identifiers specifically because it could identify color through glassware such as beakers, flasks, and graduated cylinders. The Mobile Speak was also unique in that its software analyzed primary colors via digital .jpg images, and then announced color information along with a ranking of the intensity. Unfortunately, however, shadows and angles influenced the device’s accuracy.
Other commercial color identifiers, including the Brytech Color Teller and CareTec Colorino (both available from Independent Living Aids), detect colors only through direct contact with the colored objects and are unable to ascertain the colors of liquids through glass. Many color identifiers currently on the market also have minimal accuracy at best, and all require calibration with a white surface before use.

While commercial technologies such as Vernier probes, the ID Mate II, and Mobile Speak are useful for BLV students in laboratory classrooms, they are not sufficient in themselves to empower independent science experiences and full inclusion in lab group activities. Another disadvantage of the ID Mate II and the Mobile Speak is that they are quite expensive. Additional types of hardware and software tools were necessary, but either did not exist or had not been commercialized for wide use. Therefore, the ILAB team sought to design, develop, and field test a suite of multisensory technologies to address the gaps in functionality inherent in the existing commercially available tools and technologies. Premier among these developments was the JAWS/Logger Pro interface.

**JAWS/Logger Pro Software Interface**

JAWS scripts are software files that allow JAWS to interface with other applications. JAWS is designed to work straight out of the box with a number of standard software programs such as Microsoft Office, basic Web browsers, and e-mail clients. Beyond these basic functions, JAWS provides varying levels of speech access to Web sites and other software applications, ranging from excellent access to next to none. Accessibility barriers can be minimized when a programmer trained in the JAWS
scripting language writes program files to allow JAWS to more successfully interface with a wider variety of applications (Supalo, 2007; Supalo et al., 2007; Supalo et al., 2009b). The ILAB script files for JAWS/Logger Pro have gone through several iterations and improvements based on subject feedback and needs, successfully allowing the JAWS screen reader to relate all data displayed on Logger Pro. Currently, we have scripted for JAWS versions 7.0-11.0 and Logger Pro 3.8.2.

To minimize the need for scripting as newer versions of JAWS and Logger Pro were developed, meetings were held between software engineers at Vernier and the ILAB computer programmer to discuss how the two software platforms could interact with each other more seamlessly. These meetings proved useful for eliminating some of the key challenges in achieving the JAWS/Logger Pro interface.

A number of experiments were adapted for students with BLV using the Vernier laboratory probe line in conjunction with the Logger Pro data collection software package and JAWS. A set of hotkeys allows students with BLV to listen to real-time probe readings from Logger Pro. For example, the control+shift+S keystroke announces the order of the probes displayed on the sensor line. Corresponding real-time probe readings are announced by using keystrokes such as control+shift+1 to announce the first probe’s readings, control+shift+2 for the second probe’s readings, and so forth. Control+shift+A announces all objects on the screen, including descriptions of X-Y Cartesian graphs, real-time probe readings (both digital and analog), and data tables (Supalo et al., 2007; Supalo et al., 2009a; Supalo et al., 2009b).

All pull-down Logger Pro menus are accessible through JAWS. Logger Pro also allows the use of the space bar to start and stop data collection, giving BLV students
greater control over the process. Once collection has concluded, data can be exported into Microsoft Excel, with which BLV students may eliminate bad data points and construct a best-fit line (Supalo et al., 2009a).

Through close work between the ILAB team and Vernier, a series of additional improvements have been incorporated into Logger Pro over the years. The most notable of these is the creation of an audio trace graph function so students with BLV, once they have concluded a data collection, can obtain a qualitative representation of the resulting X-Y Cartesian graph through a tone output that modulates as the slope of the graph changes. This function is available to all Logger Pro users under the “Accessibility Features” menu. There is also a real-time audio output feature that changes in tone while a probe is in use.

A command key structure was additionally incorporated with Logger Pro to allow JAWS users to access information presented in onscreen statistics boxes. The command keys provide access to the statistical information with fewer key strokes than would otherwise be necessary. This eliminated the need for BLV students to repeatedly use the tab key to search for specific statistical items under the various Logger Pro submenus. When a data table is selected, the up, down, left, and right arrows navigate the columns and rows, which are read along with the data displayed at each data point. Logger Pro statistics boxes are created from the desired data tables and accessed under the “Analyze” menu. These statistics boxes are displayed visually on the Logger Pro screen. BLV students can control+tab through the onscreen objects, such as graphs and data tables, to the desired statistics box. The JAWS command structure provides BLV students the option of identifying sensors and object fields. The command key, which is the left
bracket key, says “Command” when pressed. Pressing the “F” key accesses object fields, and the “S” key accesses the sensors. For object fields, specific pieces of data in the statistics box are numbered from 1 to 10 left to right, and may include the mean, median, mode, standard deviation, and other pivotal information. For sensors, pressing “S” allows access to real-time probe readings, likewise numbered from 1 to 10.

The JAWS screen reader also provides for the use of a refreshable Braille display with the data tables. A refreshable Braille display is a device with a series of pins oriented in six- or eight-dot Braille cells aligned in a row. The location of the cursor determines which line of text appears on the Braille display. The pins change their Braille letter/number representations as the cursor is moved up, down, left, or right across the Logger Pro screen.

**High-Tech Hardware Developed by ILAB**

To design and develop BLV-accessible hardware tools, a partnership was established between ILAB and the Chemistry Department’s Research Instruments Facility at Pennsylvania State University. Various prototype units were constructed to perform specific laboratory-related tasks as identified by the ILAB team. Resulting tools include the:

**Submersible Audible Light Sensor (SALS)**

The SALS is a battery-powered device that registers color changes or precipitate formation within solutions in real time, and is the only known submersible light sensor with audio frequency output for BLV accessibility (Supalo et al., 2006; Supalo et al.,
2008; Supalo et al., 2009a). The design is user friendly, has talking controls and output, and should be commercially cost effective. The SALS is based on a photocell that measures light intensity changes. The photocell is encased in a transparent wand small enough to allow for measurements to be taken in ordinary test tubes or beakers. The test tube or beaker is placed over a lightbox or white reflective surface such as a piece of printer paper (see Figure 5-1). As the reaction proceeds, measurements of the varying light intensity at the tip of the sensor wand are converted electronically to audible tones (Supalo et al., 2009a). The chemical change (e.g., how cloudy or dark the solution becomes) is indicated by a pronounced alteration in pitch, usually from high (for clear liquids) to low (for darker liquids and precipitates).

Figure 5-1: Monitoring color change during a chemical reaction using the SALS and a lightbox (Supalo et al., 2009a).

The SALS control box has a memory function that allows reference pitches and data pitches to be stored, and can output this information directly as audible tones or as
spoken frequency values (Supalo et al., 2009a). One limitation of the device is its use of ambient light to provide tone measurements, since ambient light levels are often variable. The SALS is also sensitive to shadows on the workspace, such as those cast by students. Therefore, all students must be advised of these limitations prior to SALS use.

Many of the experiments done in general chemistry laboratories (e.g., titrations, qualitative analyses of solutions, oxidation/reduction, precipitation, flame tests) involve visual observations. Experiments from Wilbraham et al.’s *Chemistry Laboratory Manual* (2005) were used as a representative set of activities for adaptation with the SALS. The performance of the SALS was particularly tested in detail with the iodine clock reaction, in which a starch/iodine indicator signals the changes that occur as an oxidation/reduction reaction proceeds. The times at which the relatively abrupt changes occur depend on the initial concentrations of the reagents. The reaction involves sequential changes from colorless to blue, green, brown, and, ultimately, black, corresponding to an absorbance initially in the non-visible range of the red spectral region at about 600 nm then gradually shifting to cover the entire spectrum. The SALS tone output changes by more than one octave over the 1-2 minute course of the reaction. In this adaptation of Wilbraham et al.’s experiment, a test tube is held in a rack above a lightbox, and the SALS probe is immersed in the solution. This reaction can be performed while using a talking timer (commercially available from Independent Living Aids and other vendors) to record the intervals at which the color changes occur.

The SALS control box can also be fitted with a simple conductivity probe, allowing it to detect the conductivity difference between two solutions; for example, aqueous and non-aqueous layers in a separatory funnel (Supalo et al., 2009a). This allows
BLV students to use the funnel in organic chemistry experiments to detect the point at which the denser solution passes completely through the stopcock at the bottom. Figure 5-2 shows the conductivity probe attached to a 25 mL volumetric pipette, which can be immersed in the separatory funnel. This arrangement was developed for a biodiesel synthesis/separation experiment performed by 20 high school students with BLV at the National Federation of the Blind (NFB) Youth Slam summer science camp in 2007 (Supalo et al., 2009a; Supalo et al., 2009b).

Figure 5-2: A simple ionic conductivity probe (consisting of two insulated wires exposed at the tip with a gap between them) can be used with the SALS control box to convert conductivity to audible pitch (Supalo et al., 2009a).
Color Analysis Laboratory Sensor (CALS)

The CALS has talking controls similar to those of the SALS, but can report the color of a solution (through glass) or a solid, either as spoken language or as numerical red-green-blue (RGB) and total light readings. The device has two modes (solids and liquids) and three types of probes – for solids, liquids in test tubes, and liquids in beakers, all three of which plug into the same port on the battery-powered talking control box. Unlike the SALS, the CALS does not report values continuously but speaks the colors or gives the RGB readings 2-5 seconds after the appropriate button has been pushed. Figure 5-3 shows the CALS with a test tube probe and a solids probe.

Figure 5-3: The CALS control box with a test tube probe (left) and a solids probe (right).

The test tube probe and beaker probe determine the color of light transmitted through solutions and give very accurate readings. Additionally, the liquid mode for use with the test tube and beaker probes factors into its software an algorithm that accounts for the diffraction of light through glass. The solids probe uses reflected light and is less accurate in reporting the dominant color; for example, confusing red and pink, or brown and yellow. However, the RGB readings with the solids probe report the intensity of the
various components of the detected color and are highly consistent and reproducible. Prior to use, the solids probe is calibrated by holding the sensor to a piece of white paper; the test tube and beaker probes must be calibrated on a clear solution.

**Talking Voltmeter and Scientific Talking Stopwatch (STS)**

The Talking Voltmeter and the STS (with 0.01-second accuracy) were developed, constructed, and optimized through several generations of design and testing. These are low-cost items like the SALS and CALS, and have similar talking hand-held control boxes. The STS can be actuated either by pushing a button on the controller or by using external light- or force-sensitive microswitches, and can be interfaced with photogate technology and other motion sensors to detect the start and stop times of the motion of objects on either a track or flat surface.

In addition to usage in the ILAB project, the NFB’s Youth Slam, and similar events, the SALS sensor and other high-tech ILAB tools have been incorporated into nanoscale experiments developed at the University of Wisconsin-Madison’s Nanoscale Science and Engineering Center (NSEC, [http://www.nsec.wisc.edu](http://www.nsec.wisc.edu)). The NSEC has designed several activities to teach university students who are BLV about nanoscale science. Related hands-on workshops were developed and field tested at NFB annual conventions during the summers of 2006-09.
Low-Tech Laboratory Tools

All components of the suite of low-tech laboratory tools from Science Activities for the Visually Impaired/Science Enrichment for Learners with Physical Handicaps (SAVI/SELPH, discussed in Chapter 2), developed more than three decades ago at the Lawrence Hall of Science at UC-Berkeley for students with BLV, can still be obtained through various vendors on the Internet. The ILAB project incorporated some of these tools, most notably the notched syringes for liquid measurements, Braille-labeled floaters for graduated cylinders, and the use of serving trays as workspace organizers (Supalo et al., 2008). Figure 5-4 illustrates some of these items.

Figure 5-4: A notched syringe (left) and a float with tactile glue markers in a 50 mL graduated cylinder (right) are used for measuring liquid volumes.

Cafeteria-style serving trays were useful in assisting BLV students with keeping glassware and probes organized on the lab bench and served as tactile markers for students to know where equipment was placed. This setup also aided teachers by providing a clearly defined area in which to place glassware and other tools being used
by students with BLV. Additionally, the investigator found that placing a rubberized, non-skid bath mat in front of a sink helped students to tactilely identify where the sink was located; this strategy was incorporated into all ILAB-participating classrooms. Some teachers participating in the ILAB project found that putting the JAWS-equipped desktop computer onto a wheeled cart allowed for it to be easily brought out during lab sessions, and safely stored under lock and key when not in use.

Additionally utilized by ILAB was a laboratory bench-top setup primarily designed by Dr. Lillian Rankel of Hopewell Valley Central High School in Pennington, New Jersey, in conjunction with the ILAB team. As pictured in Figure 5-5, the bench is

*Figure 5-5: A properly designed laboratory bench is one of the most important elements of safe and effective laboratory practice for students with BLV. The lab bench pictured here was designed by Dr. Lillian Rankel of Hopewell Valley Central High School.*
ready for an acid/base titration. A Vernier drop counter, pH electrode, and buret are on the right, above a magnetic stir plate. In front of the stir plate is an Ohaus balance, which is connected to a laptop computer. In front of the computer is a SALS control box. At the far left are a green plastic waste container and a roll of paper towels on a ring-stand rod. Both ring-stand rods have brightly colored tennis balls on top as visual cues for low-vision students and to help prevent injury. A flat container (not shown) holds a number of notched Braille-labeled syringes for delivering different volumes of liquids.

**Summary**

The goal of the ILAB project was to develop multisensory tools to provide students who are BLV with educational opportunities for effective hands-on learning experiences in their science classrooms. This included the ability for them to more fully contribute toward the completion of laboratory goals as members of lab groups consisting primarily of sighted students. Overlooking the science learning of BLV students dispossesses them of the adequate education that is the right of all U.S. citizens and robs the nation of the potential scientific contributions of a substantial subset of the U.S. population.

The investigator intends to continue development of accessible technologies for K-12 students, college students, and professionals with BLV, and to commercialize these tools for wide use in schools and laboratories across the country and around the world.

It would be fair to add students with disabilities to the underserved populations mentioned in the following statement from Rutherford and Ahlgren’s *Science for All Americans* (1990, p. 200): “When democratic realities, national needs, and democratic
values are taken into account, it becomes clear that the nation can no longer ignore the science education of any students. Race, language, sex, or economic circumstances must no longer be permitted to be factors in determining who does and who does not receive a good education in science, mathematics, and technology. To neglect the science education of any … is to deprive them of a basic education, handicap them for life, and deprive the nation of talented workers and informed citizens – a loss the nation can ill afford.”
Chapter 6

Badger High School Case Study

Badger High School (a pseudonym) is located in the suburbs of a major metropolitan Midwestern city in the United States. This school includes the traditional grades of ninth through twelfth. The mission of Badger High School is to maintain a student-based learning environment that allows faculty to think “outside the box.” Research opportunities and new technologies are welcome at Badger in the hope of providing innovative learning experiences for students and teachers.

Demographics of School

Badger High School has a student body of approximately 3,000, with 53% male and 47% female. At the time of this study, the school had nine science and math faculty members, eight of whom had a master’s degree or higher. Reported student racial breakdown was white 82.1%, Asian 7.6%, African-American 6.2%, Hispanic 3.1%, and Native American 1.0%. Limited English proficiency was 4.5%, and special education students comprised 10%. Eligibility for free or reduced-price lunch was 26.5%.

Background of Student

Nate (a pseudonym) was a 17-year-old junior enrolled in high school chemistry. He reported his visual acuity at approximately 20/400. He was able to see outlines of objects and people, as well as print from approximately three inches from the page. Nate was also able to perceive some colors but not others, and depended on good lighting for
effective color recognition. He used Braille and a BrailleNote note-taker device. Nate indicated an interest in science as a possible profession, and also expressed interest in the music and law professions. Nate previously had enrolled in a physical science class and a biology class, both of which included lab components. He had used his residual vision to conduct experiments independently, but also was part of a group at times. He said group partners were changed from class to class. Sometimes he had been able to choose his lab partners, and other times his teacher assigned partners. Even though he wanted to participate in every aspect of experiments with his group partners, Nate had often been given the task of data recorder because he could not see well enough to make detailed observations. He indicated no apprehension toward his upcoming chemistry class.

**Background of Teacher**

The teacher from Badger High School was given the pseudonym of BT Donald (Badger teacher Donald). BT Donald had been teaching at Badger for a number of years, but Nate was his first BLV student. He taught several chemistry classes, from introductory to honors to advanced placement (AP). BT Donald preferred to use Vernier equipment whenever possible in his lab curricula. He based lab group size on the quantity of Vernier lab equipment available, averaging four students per group. When determining groups, BT Donald based assignments on a random approach, using variables such as height, gender, and side of the room. His classroom was equipped with Smart Board technology to assist with lecture materials, as well as the components necessary for laboratory experiments. BT Donald used a very hands-off approach to working with his students in laboratory activities and encouraged them to read over the experiment
materials prior to coming to class. He believed that this method not only left more of the
problem-solving to the students, but also helped them exercise more independence while
conducting experiments. BT Donald also enjoyed playing various types of music to serve
as background during lab sessions. Additionally, he stated he had limited time available
to get to know his students.

The investigator provided minimal Vernier lab equipment since BT Donald
already used this equipment with the rest of his classes. Thus, Nate used most of the same
standard hardware tools as did his sighted classmates.

Classroom Resources

The Badger chemistry classroom was equipped with bench-top counters having
lab equipment drawers and sinks at each station. The classroom also contained desks for
student use during lectures. BT Donald used PC computers with Vernier equipment. All
the students used Logger Pro, along with Microsoft Word and Excel to prepare lab
reports. Class periods were approximately 90 minutes in length as a result of covering
what traditionally would have been two semesters of content during one semester for this
course. BT Donald provided storage space for Nate’s extra lab equipment. All students
were required to use eye protection, and the class was equipped with all required safety
materials. Textbooks and information on laboratory procedures were provided to Nate in
Braille. He took notes on his laptop computer and performed calculations on his
BrailleNote notetaker via the scientific calculator functions.
Relationship between Investigator, Teacher, BLV Student, and Parents

The investigator had direct communication with Nate via email and telephone throughout the school year. The conversations usually involved how to use ILAB tools or textbook chemistry concepts. On several occasions, the investigator assisted Nate with chemistry homework problems via telephone.

The investigator likewise communicated with BT Donald via email and telephone. Additionally, BT Donald participated in ILAB team conference calls every 60 days, giving him the opportunity to share his experiences as well as learn from other teachers participating in the ILAB study. The conference calls also served as a way for the investigator to receive feedback regarding how the ILAB tools were being implemented in the various classrooms.

Most of the investigator’s parental communications were with Nate’s mother, and only rarely involved Nate’s father. As the school year went on, disagreements were observed between the mother, Nate, and BT Donald as to how certain aspects of the chemistry curriculum should be interpreted and evaluated. These disagreements led BT Donald to wonder whether ILAB participation was increasing the political pressures being exerted on him and on how he was teaching his class. BT Donald indicated to the investigator at the beginning of the school year a concern with Nate’s mother’s strong views, high expectations, and high level of involvement with school matters. He was also not sure what to expect from his new pupil. These perceived pressures may have negatively impacted the relationship between BT Donald and the investigator. Although BT Donald fulfilled every obligation as an ILAB participating teacher, he did so with declining enthusiasm as the semester went on.
Interview Data

The following are excerpts and/or summaries of dialogue between the investigator and the BLV student, and between the investigator and the teacher. The questions asked were based on the standard interview scripts for the ILAB study (Tables 4-1, 4-2, 4-3); follow-up questions for clarification were also asked, dependent on the student’s or teacher’s responses to the initial queries. These particular questions were chosen for analysis because of their significance to the incorporation of the BLV student into lab groups, his efficacy with the ILAB tools, and his interest in science. Commentary from the investigator follows the excerpts/summaries for each interview.

Excerpts, Summaries, Commentary: Pre-School-Year Student Interview

Have you been in any mainstream science classes to date?

“Physical science 9, biology, honors physical science 9, and honors biology 1.”

The interview indicated that all these classes involved laboratory components.

Can you describe for me how you conducted your participation in those labs?

“Sometimes the experiment was well enough where I could actually do the experiment, but every so often there would be an experiment where I would just have to sit back and keep data, and it was sort of a mix of either me doing the experiment or me just having to sit back because I can’t see well enough to do the experiment.”

Did you like that level of participation or did you want something else?

“I was wanting more participation. I was wanting to participate in every aspect of the experiment.”
Do you have any apprehension or excitement about your upcoming chemistry class?

Nate indicated he had no apprehension toward his chemistry class. He said he was excited to mix chemicals together and work with different elements in the lab.

Investigator Commentary: Nate has some useable vision and previously depended on this vision to have hands-on experiences in science lab classes. His level of vision influenced his level of involvement. He exhibited excitement for his use of the ILAB tools, and said he hoped to have greater participation in lab.

Excerpts, Summaries, Commentary: Post-School-Year Student Interview

What was your favorite part of the chemistry class this year?

“I would say my favorite part has been the labs.”

Any particular reason why?

“Mostly because you actually get to do stuff and it’s not just sitting taking notes, listening. I actually like to do things.... I actually liked the laboratory part best because I actually get to do things and I actually get to participate in the lab, in laboratory experiments.”

How did you share responsibility in the lab?

“I tried to take charge and do some things.... It just seems like some people in this world have their minds set, like concrete.”

Do you think your visual impairment makes working in labs more difficult?

“I think the only part that would make it more difficult is that it seems like it might, how
do I put this? It seems like it might take maybe not more time to learn the stuff, but more
time to just make people realize that you can participate and not just sit there.”

_When you’re working as part of a team, do you tend to work on the things that are easiest
for you to do?_

“Sometimes I do. I don’t know. I like to challenge myself.”

_Do you think this class helped you to realize that you could do science and that it
wouldn’t be too hard for you even if you may not necessarily have liked the material?_

“It made me realize that I can actually do an experiment.”

_Do you think this class helped or hindered your desire to be a scientist?_

“I think it helped my desire to want to be a scientist because it made me realize that I can
do the science.”

_Investigator Commentary:_ Nate said he had an increased level of participation as a result
of the ILAB tool intervention. He has a new outlook on science because he is able to
participate in the experiments. He complemented the use of his residual vision with the
ILAB tools. The hands-on component of the labs was the most enjoyable part of the class
for Nate. Hands-on experiences reinforced his learning in this chemistry class. His
participation, although partners changed from lab to lab, seemed to be mostly positive.
He indicated he encountered some lab partners who did not perceive him as capable of
completing the work. He realizes this misconception by sighted peers is going to be part
of his everyday life.
**Excerpts, Summaries, Commentary: Post-School-Year Teacher Interview**

*How well did Nate work with sighted students from the class in the labs?*

“I think some of the sighted students have a little bit of trepidation because they’ve never worked with a blind student before.”

*When working with the group, have you seen Nate only doing things he’s comfortable with or have you seen him doing all kinds of things?*

“I’ve seen him trying all kinds of things, mostly in accordance with whatever the technology allows.”

*As far as you know, is his efficacy with the ILAB technology fairly high?*

“Yes, because the technology is still pretty basic. He’s doing just fine.”

*How does the student’s visual impairment affect his participation in the class?*

BT Donald indicated that he thought the impact was minimal except in respect to labs using Bunsen burners or flames, due to safety concerns.

**Investigator Commentary:** BT Donald indicated Nate had performed well with the ILAB tools and tried to vary his tasks in the lab. However, he stated that Nate worked well with the ILAB tools because they have only basic functionality. He said Nate varied his tasks only as far as the technology would permit. Lab group members exhibited some level of discomfort when working with Nate. BT Donald tended to rotate lab partners for Nate every lab session, which required Nate to describe his ILAB tools and how he performed lab work to most of his classmates. Having rotating lab partners may have limited Nate’s
ability to establish team rapport, thus making it more difficult for him to contribute from
group to group.

**SAI II Survey Data Pre/Post School Year**

Nate’s SAI II survey data appear in Table 6-1. The table indicates the six
attitudinal constructs, as discussed in Chapter 4. The Likert score totals for each construct
are from the 40 questions in the SAI II instrument (see Table 4-4 in Chapter 4), with
positive questions categorized as “A” and negative questions categorized as “B.” The “B”
questions were reverse-coded for point values, meaning that higher scores indicate better
attitudes both for the “A” and “B” questions, as described in Chapter 4. At the bottom of
the table are total shifts in attitude for all “A” items and all “B” items, and a total for “A”
and “B” together.

Nate exhibited a 2-point improvement in attitude toward science in each of
constructs #3 and #5, and a 1-point improvement in each of constructs #1 and #6.
Conversely, he saw a 3-point decline in attitude for construct #2 and a 2-point decline in
construct #4. His “all A” total shows a 4-point improvement, but his “all B” total shows a
3-point decline, combining for an overall attitude improvement of just 1 point. He was
substantially positive about science both before participating in the ILAB study and
afterward, as illustrated by “all AB” totals of 151 and 152.
### Table 6-1: SAI II Data for Nate, Pre/Post School Year 2007-08

<table>
<thead>
<tr>
<th>Attitudinal Construct</th>
<th>Pre-Year</th>
<th>Post-Year</th>
<th>Difference Pre/Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-A</td>
<td>12</td>
<td>10</td>
<td>-2</td>
</tr>
<tr>
<td>1-B</td>
<td>10</td>
<td>13</td>
<td>+3</td>
</tr>
<tr>
<td>2-A</td>
<td>12</td>
<td>13</td>
<td>+1</td>
</tr>
<tr>
<td>2-B</td>
<td>11</td>
<td>7</td>
<td>-4</td>
</tr>
<tr>
<td>3-A</td>
<td>12</td>
<td>13</td>
<td>+1</td>
</tr>
<tr>
<td>3-B</td>
<td>12</td>
<td>13</td>
<td>+1</td>
</tr>
<tr>
<td>4-A</td>
<td>12</td>
<td>13</td>
<td>+1</td>
</tr>
<tr>
<td>4-B</td>
<td>8</td>
<td>5</td>
<td>-3</td>
</tr>
<tr>
<td>5-A</td>
<td>8</td>
<td>10</td>
<td>+2</td>
</tr>
<tr>
<td>5-B</td>
<td>12</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>6-A</td>
<td>21</td>
<td>22</td>
<td>+1</td>
</tr>
<tr>
<td>6-B</td>
<td>21</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>All A</td>
<td>77</td>
<td>81</td>
<td>+4</td>
</tr>
<tr>
<td>All B</td>
<td>74</td>
<td>71</td>
<td>-3</td>
</tr>
<tr>
<td>All AB</td>
<td>151</td>
<td>152</td>
<td>+1</td>
</tr>
</tbody>
</table>
Overview of the Five Laboratory Lessons

This section contains synopses of what occurred in each of the five audio-video-recorded laboratory lessons. The lessons were part of the school’s regular curriculum. The following descriptions were written from the lesson transcripts. The synopses are not intended as complete representations of activities during each lesson, but rather are intended to provide readers with an idea of what the BLV student experienced. Short descriptions regarding how the BLV student interacted with his group partners are also included. Nate did not have more than one partner at a time during any of the lessons, so each of his lab groups comprised a total of two people.

Please note that while the lessons not incorporating the ILAB tools are listed first, they did not necessarily precede the lessons with ILAB tools chronologically. However, the two N-lessons are chronological in relationship to each other, as are the three I-lessons. The I-lessons are listed in the order in which they actually occurred to better illustrate the BLV student’s progress, if any.

Lesson 1 Synopsis: Density of a Sugar Solution (N-Video)

At the beginning of the experiment, Nate and his sighted lab partner were unsure how much water was in the graduated cylinder because the gradation lines weren’t clearly marked. They had to ask their classmates for clarification. Nate used his notched syringe to add water to the graduated cylinder. Nate’s lab partner helped him adjust the balance to measure the weight of the sugar. During the experiment, Nate and his lab partner were unsure how much sugar to add to the 100 mL water they had measured out, and they asked a classmate for assistance. They were uncertain how much sugar would be
needed to make a 5% standard sugar solution, because the density, mass, and volume relationship wasn’t known by Nate and his partner. Instead of adding 95 grams of water with 5 grams of sugar to make the 5% sugar solution, 95 mL water were added with the 5 grams of sugar. BT Donald advised them to use a glass stirring rod to stir their solution, but no stirring rod was found in their drawers, and they used much time looking for it near the end of class. Much time was also spent near the end of the class trying to figure out how much water was weighed in the balance, and minutes were running short to make a second trial. A few minutes before class ended, Nate and his lab partner were calculating and trying to analyze the mass and volume of the water/sugar solution to determine its density. Much of their time had been spent trying to figure out how to make the solution.

**Lesson 2 Synopsis: Separation of the Components of a Mixture (N-Video)**

The transcript reflects very little dialogue for this experiment. Nate put a watch glass containing a solid substance in the ring stand. The Bunsen burner was lit and moved to the ring stand by Nate’s lab partner while Nate read some of the procedure information using JAWS. Nate and his partner watched while the item was heated, then the partner used tongs to remove the container from the ring stand. Nate turned the gas off, and they waited for the item to cool. Then Nate measured the mass, made some calculations, and worked on his computer. Next they put a second sample on the balance, and Nate did some calculations. There was little interaction with BT Donald.
Lesson 3 Synopsis: Boiling Point Determination (I-Video)

The boiling point of water was determined at standard atmospheric pressure (indicated by a barometer in the classroom). At the beginning of the experiment, Nate set up the Vernier LabPro device while his lab partner set up the Bunsen burner and a beaker of slushy ice water. It was clearly evident from the transcript that some problems occurred with the Vernier LabPro, and BT Donald inspected the device to see if it was working properly. Nate inserted the temperature probe into the beaker to determine the temperature of the slushy ice water while his lab partner assisted, adding more ice to keep the temperature close to 0°C Celsius. Through the use of JAWS, Nate determined the temperature readings every few seconds. During the lighting of the Bunsen burner, Nate’s lab partner assisted because doing so was in the best interest for Nate’s safety. It was revealed through the transcript utterances that Nate and his lab partner were confused about the overall objective of the experiment. Nate’s lab partner said they needed to figure out how well the thermometer worked. At the end of the experiment Nate and his partner were confused what “mmHg” stood for, and guessed it was “millimeter hectograms” instead of millimeters of mercury (a unit of atmospheric pressure).

Lesson 4 Synopsis: Solubility of an Unknown (I-Video)

At the beginning of the experiment, BT Donald showed students how to set up the apparatus for boiling. Nate was very involved in this experiment. Nate weighed the 10 mL graduated cylinder, set up the ring stand, and worked on the LabPro and the computer. As the procedure became more difficult during the experiment, BT Donald had to provide more input, putting the beaker on a stir plate and helping adjust the ring stand.
as well as the test tube clamp. Nate and his lab partner patiently worked together, collaborating to read the temperature of the unknown chemical and observing physical changes while heating the solution. At the end of the experiment, they agreed that the unknown chemical had dissolved in the water.

Lesson 5 Synopsis: Which Is Your Metal? (I-Video)

At the beginning of the experiment, Nate set up the Vernier LabPro with the computer and explained to his partner how it functioned. Nate’s partner set up the scale to determine the mass of the metal. Because the procedure information had not been converted to Braille, Nate was in a disadvantaged position, but he easily adapted by asking questions of BT Donald. Nate was involved in the experiment and helped troubleshoot the balance with his lab partner. Nate also used his BrailleNote to take notes of important data for the experiment. Nate and his partner were both confused as to how to measure the initial temperature of the metal. Nate measured the temperature of the water inside the calorimeter cup with a digital thermometer. From the transcript it was evident that BT Donald was very engaged in the activities and assisted throughout the experiment, setting up the proper equipment and data collection procedures.

Video Task Analysis for Each Lesson

The following five tables (6-2 through 6-6) were constructed to classify the types of tasks performed by Nate within each lesson. Excerpts from the transcripts of the corresponding lab group actions and dialogue are included following each table. The time stamp for each task, a description of the task performed, whether or not the task involved
ILAB tools, and the task number (assigned consecutively for each chronological, discrete task that appears in each table, indicated so as to relate individual tasks in the tables to the appropriate transcript excerpts) are shown. (Note: Sometimes working on the computer is categorized as an ILAB-tool task and sometimes as a non-ILAB-tool task; the selection of “I” or “N” was based on whether the computer was being used along with an ILAB tool to take a data point or simply to take notes or perform calculations.) As stated in Chapter 4, not all actions in the video task analysis were necessarily directed toward laboratory goals. The selected tasks are not inclusive but were chosen as illustrative to provide an overview of the types of tasks and dialogue that occurred within each lesson.
Lesson 1 Analysis: Density of a Sugar Solution (N-Video)

Table 6-2: Lesson 1 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:03.6 - 0:15.2</td>
<td>Looking for syringe in drawer</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>1:57.7 - 2:10.6</td>
<td>Puts notched syringe to top of water container</td>
<td>I</td>
<td>2</td>
</tr>
<tr>
<td>2:18.0 - 2:35.7</td>
<td>Leans over partner to fill water container</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>2:41.8 - 2:44.6</td>
<td>Draws water into notched syringe</td>
<td>I</td>
<td>4</td>
</tr>
<tr>
<td>2:48.1 - 2:54.8</td>
<td>Tries to push water from syringe into cylinder</td>
<td>I</td>
<td>5</td>
</tr>
<tr>
<td>5:25.5 - 5:35.3</td>
<td>Pulls water into syringe</td>
<td>I</td>
<td>6</td>
</tr>
<tr>
<td>5:36.9 - 5:41.5</td>
<td>Uses syringe to put water into graduated cylinder</td>
<td>I</td>
<td>7</td>
</tr>
<tr>
<td>8:10.4 - 8:53.9</td>
<td>Adjusts the scale</td>
<td>N</td>
<td>8</td>
</tr>
<tr>
<td>12:36.7 - 12:49.2</td>
<td>Unscrews bottle and pours water into beaker</td>
<td>N</td>
<td>9</td>
</tr>
<tr>
<td>22:15.6 - 22:23.9</td>
<td>Pours some water out of graduated cylinder</td>
<td>N</td>
<td>10</td>
</tr>
<tr>
<td>23:18.7 - 23:59.5</td>
<td>Adjusts balance</td>
<td>N</td>
<td>11</td>
</tr>
<tr>
<td>27:34.4 - 27:39.4</td>
<td>Pulls out calculator</td>
<td>N</td>
<td>12</td>
</tr>
<tr>
<td>29:26.4 - 29:30.7</td>
<td>Pours sugar into water</td>
<td>N</td>
<td>13</td>
</tr>
<tr>
<td>29:32.9 - 29:42.0</td>
<td>Swirls sugar mixture</td>
<td>N</td>
<td>14</td>
</tr>
<tr>
<td>29:48.0 - 29:53.5</td>
<td>Swirls sugar mixture</td>
<td>N</td>
<td>15</td>
</tr>
<tr>
<td>38:04.3 - 38:11.0</td>
<td>Works on BrailleNote</td>
<td>N</td>
<td>16</td>
</tr>
<tr>
<td>39:00.2 - 39:22.4</td>
<td>Works on balance</td>
<td>N</td>
<td>17</td>
</tr>
<tr>
<td>39:32.1 - 39:44.3</td>
<td>Works on calculator</td>
<td>N</td>
<td>18</td>
</tr>
<tr>
<td>41:12.6 - 41:26.2</td>
<td>Works on calculator</td>
<td>N</td>
<td>19</td>
</tr>
<tr>
<td>41:27.8 - 41:31.7</td>
<td>Works on BrailleNote</td>
<td>N</td>
<td>20</td>
</tr>
<tr>
<td>42:29.2 - 42:41.7</td>
<td>Puts away papers and materials</td>
<td>N</td>
<td>21</td>
</tr>
</tbody>
</table>
**Task 1**

Nate: I need to get that, um, syringe.
Nate: [Looking for syringe in drawer.]
BT Donald: Nate, you never did a ... for this lab, we’ll let it for the next lab.
Nate: Okay.
Nate: Where is that syringe?
Partner 1: Syringe?
Nate: Oh, there it is.
Nate: Notched syringe.

**Tasks 2-5**

Nate: [Puts notched syringe to top of water container.]
Nate: How much do we need? How much water do we need?
Nate: [Leans over partner to fill water container.]
Nate: Do we need like 10 mL?
Nate: Let’s see if anything gets sucked up in here.
Nate: [Tries to draw water into notched syringe.]
Nate: [Tries to push water out into cylinder.]
Nate: Did anything come out?
Partner 1: No.
Nate: So that obviously means that we need a little cup.

**Tasks 6-7**

Nate: [Pulls water into syringe.]
Partner 1: Is it 10?
Nate: Yeah.
Nate: [Uses syringe to put water in the graduated cylinder.]
Partner 1: [Looks at lines on the graduated cylinder.]
Partner 1: Fine, that’s good.
Nate: Perfect.
Nate: Okay, there we go, so.

**Task 8**

Nate: [Adjusts the scale.]
Partner 1: [Helps Nate adjust the scale.]
Partner 1: So, is it zeroed?
Nate: Yeah.
Partner 1: Should we go ... 15 grams of sugar?
**Task 9**

Partner 1: Can’t you just pour it in?
Nate: What, oh, pour it in? That works, too.
Nate: [Unscrews bottle and pours water into beaker.]
Partner 1: No, I meant pour it into here.
Nate: And maybe if I do it like [interrupted].
Partner 1: See this, I was thinking we could just pour it into here, look.  
Partner 1: [Pours water from container into beaker.]
Partner 1: Oh, crap, I forgot to measure it.

**Task 10**

Partner 1: This is over 100 now.
Nate: Over 100?
Partner 1: Do you want me to just pour it? Like so it’s accurate?
Partner 1: Just pour some of it out.
Nate: [Pours some water out of graduated cylinder.]
Nate: It’s still over 100, right?
Partner 1: Yeah.

**Task 11**

Nate: We’ll measure this first.
Nate: [Adjusts balance.]
Partner 1: Nope. Almost. Smooth that one out a little more.
Partner 1: [Adjusts balance.]
Partner 1: Oh, my gosh, I don’t know why it’s not going.

**Task 12**

Nate: Okay, so, what is it?
Nate: [Pulls out calculator.]
Nate: Okay, so what is the mass of that?
Nate: It should be about 27 point something to get 5. It should be about 27.3 to get 5 grams.
Partner 1: It’s about 27.7?
Nate: Okay, so then we should probably just take out a tiny [interrupted].

**Tasks 13-15**

Nate: I need to put this in here, I think.
Nate: [Pours sugar into water.]
Partner 1: Are you sure? That’s a lot of sugar, man.
Nate: [Swirls sugar mixture.]
Nate: Mix it around.
Nate: I think so. I don’t know. I think so.
Nate: [Swirls sugar mixture.]
Nate: Mixing, mixing, mixing, mixing, mixing.

Task 16

Nate: Point what?
Partner 1: One. Point one.
Nate: [Works on BrailleNote.]
Classmate: Do we have to do a second beverage?
Partner 1: I don’t know. We haven’t even done our first one.

Tasks 17-18

Partner 1: [Starts to clean up.]
Nate: [Works on balance.]
Nate: Wait, no, is that 1.9, and it was up to there? Oh, so that would be 223.
Partner 1: Yeah.
Nate: [Works on calculator.]
Nate: So it would be 112.7.
Partner 1: Okay, so should we tell him?
Nate: Uh... yeah, yeah.

Tasks 19-20

Partner 1: 110.
Partner 1: That’s the mass of the beaker minus [interrupted].
Nate: No, no, no, the volume.
Partner 1: That was 95.
Nate: No, I mean the volume of the whole thing together.
Partner 1: 100.
Nate: 100? Oh, yeah, yeah, right.
Nate: [Works on calculator.]
Nate: 1.127.
Nate: [Works on BrailleNote.]
Partner 1: So would it be 1.127?
Partner 1: Okay.

Task 21

Nate: [Puts away papers and materials.]
Partner 1: [Puts away papers and materials.]
Partner 1: We’ll just work a little faster next time, since we’ll know what we’re doing.
Partner 1: [Puts away materials.]
Partner 1: [Wipes off lab bench.]
Investigator Commentary: In this lesson, Nate was accidentally permitted to use an ILAB notched syringe, which allowed him to participate more than he otherwise would have. (However, the time he spent using the notched syringe was not included in the analysis of his percent of time engaged with laboratory-goal-directed actions, as described in the Graphic Analysis of Video Data section later in this chapter.) Nate communicated well with his lab partner. He was fully integrated into the hands-on activities of this lesson. The use of the balance in this experiment illustrated the collaborative effort between Nate and his lab partner. The dialogue between Nate and his partner, in reference to calculations and what was occurring during the experiment, demonstrated that his ideas were being accepted. Nate used all resources at his disposal for taking notes and pouring liquids. His motivation to participate in the experiment is notable in this lesson.
Lesson 2 Analysis: Separation of the Components of a Mixture (N-Video)

Table 6-3: Lesson 2 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:15.9 - 0:22.6</td>
<td>Walks over and puts something in ring stand</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>0:50.8 - 1:38.5</td>
<td>Watches ring stand and Bunsen burner</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>1:59.1 - 2:11.4</td>
<td>Walks around and turns gas off</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>8:50.5 - 8:56.8</td>
<td>Grabs watch glass and puts it on balance</td>
<td>N</td>
<td>4</td>
</tr>
<tr>
<td>9:15.0 - 10:05.9</td>
<td>Works with data on computer</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>10:14.5 - 10:32.2</td>
<td>Grabs calculator to do calculations</td>
<td>N</td>
<td>6</td>
</tr>
<tr>
<td>10:32.4 - 11:43.2</td>
<td>Works with data on computer</td>
<td>N</td>
<td>7</td>
</tr>
<tr>
<td>12:43.0 - 12:45.7</td>
<td>Picks up calculator to do calculations</td>
<td>N</td>
<td>8</td>
</tr>
<tr>
<td>12:53.5 - 13:20.8</td>
<td>Works on computer</td>
<td>N</td>
<td>9</td>
</tr>
<tr>
<td>13:32.8 - 13:35.3</td>
<td>Works with data on computer</td>
<td>N</td>
<td>10</td>
</tr>
<tr>
<td>13:37.2 - 13:41.8</td>
<td>Works with data on computer</td>
<td>N</td>
<td>11</td>
</tr>
<tr>
<td>13:46.2 - 14:11.4</td>
<td>Works with data on computer</td>
<td>N</td>
<td>12</td>
</tr>
<tr>
<td>14:11.4 - 14:21.8</td>
<td>Moves watch glass and puts another container on the balance</td>
<td>N</td>
<td>13</td>
</tr>
<tr>
<td>14:23.8 - 14:31.2</td>
<td>Works with data on computer</td>
<td>N</td>
<td>14</td>
</tr>
<tr>
<td>14:34.7 - 14:57.8</td>
<td>Works with data on computer</td>
<td>N</td>
<td>15</td>
</tr>
<tr>
<td>18:22.4 - 18:42.6</td>
<td>Uses calculator</td>
<td>N</td>
<td>16</td>
</tr>
<tr>
<td>18:42.6 - 19:53.7</td>
<td>Works with data on computer</td>
<td>N</td>
<td>17</td>
</tr>
</tbody>
</table>

**Tasks 1-2**

BT Donald: Remember goggles, pal.
Nate: Yup.
Nate: [Walks over and puts something in ring stand.]
Nate: There we go.
Partner 1: [Lights Bunsen burner and moves it under ring stand.]
Partner 1: [Walks around to stand on the same side of the bench as Nate.]
Partner 1: [Watches ring stand and Bunsen burner.]
Nate: [Watches ring stand and Bunsen burner.]

**Task 3**

Partner 1: [Uses tongs to remove bowl from Bunsen burner.]
Partner 1: Just, uh, do you want to turn the gas off?
Nate: Yeah.
Nate: [Walks around and turns gas off.]
Nate: There.

**Task 4**

Nate: I need that watch glass.
Nate: [Grabs watch glass and puts it on balance.]
Nate: There we go.
JAWS: [JAWS reads out data.]
Nate: 75.73.

**Tasks 5-7**

Nate: [Works with data on computer.]
Nate: 75 point ... minus.
Nate: [Grabs calculator to do calculations.]
Nate: Point five seven.
Nate: [Works with data on computer.]
Nate: That would be 0.57 divided by 2.1.

**Tasks 8-15**

Nate: [Picks up calculator to do calculations.]
Nate: 0.27.
Nate: [Works on computer.]
Nate: Wait, if it’s silicon is S, no, silicon is C.
BT Donald: S. Si.
Nate: Si?
Nate: [Works with data on computer.]
Nate: Oooh!
Nate: [Works with data on computer.]
Nate: Oh, it was saying C O 2. I thought it meant like carbon dioxide.
Nate: [Works with data on computer.]
Nate: [Moves watch glass and puts another container onto the balance.]
Nate: [Works with data on computer.]
Nate: Let’s see if it changes at all.
Nate: [Works with data on computer.]
Nate: 52.42.

Tasks 16-17

Nate: And 2.03 divided by [talks through calculations]. Okay.
Nate: [Uses calculator.]
Nate: [Works with data on computer.]

Investigator Commentary: In this lesson, Nate primarily worked alone, physically conducting most of the tasks. This experiment was a makeup lab activity and was done at a different time from regular class sessions. The involvement of Nate’s lab partner was minimal. Nate used the JAWS text-to-speech screen reader on his computer but no ILAB tools. He used the computer to take notes and manipulate data. Additionally, he used his residual vision to aid in determining occurrences during each step of the experiment. Since Nate was responsible for most of the tasks in this lesson, his participation was significantly higher than it would have been had he been part of a regular lab group.
Lesson 3 Analysis: Boiling Point Determination (I-Video)

Table 6-4: Lesson 3 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00.0 - 4:40.8</td>
<td>Sets up Vernier LabPro and works on computer</td>
<td>I</td>
<td>1</td>
</tr>
<tr>
<td>6:00.1 - 6:10.4</td>
<td>Adjusts LabPro</td>
<td>I</td>
<td>2</td>
</tr>
<tr>
<td>6:18.2 - 6:35.2</td>
<td>Plugs in cord</td>
<td>I</td>
<td>3</td>
</tr>
<tr>
<td>8:08.4 - 8:24.3</td>
<td>Listens to JAWS</td>
<td>I</td>
<td>4</td>
</tr>
<tr>
<td>10:29.5 - 10:42.6</td>
<td>Works on computer</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>11:28.0 - 11:29.1</td>
<td>Takes thermometer out of water</td>
<td>N</td>
<td>6</td>
</tr>
<tr>
<td>11:36.4 - 11:39.9</td>
<td>Puts temperature probe into the beaker</td>
<td>I</td>
<td>7</td>
</tr>
<tr>
<td>16:56.8 - 17:38.4</td>
<td>Enters data on computer, stops the probe reading</td>
<td>I</td>
<td>8</td>
</tr>
<tr>
<td>18:08.7 - 18:20.6</td>
<td>Enters information into computer</td>
<td>N</td>
<td>9</td>
</tr>
</tbody>
</table>

**Task 1**

Nate: [Sets up Vernier LabPro and works on computer.]
Partner 1: [Walks over and pours water into beaker.]
Partner 1: [Plugs in gas line for Bunsen burner.]

**Tasks 2-3**

Nate: [Walks over with BT Donald.]
BT Donald: Plugged in?
BT Donald: [Checks LabPro cords.]
BT Donald: Wait a minute. That’s not going to work.
BT Donald: No, you’re fine, you’re fine. It plugs in but that’s the wrong end, it’s the wrong cord.
Partner 1: [Puts water into beaker and swirls it around.]
Nate: Oh, okay.
BT Donald: This is the one for the balance. No, leave that there, Nate.
Nate: [Adjusts LabPro.]
BT Donald: Here, let me see, uh, let me see the LabPro.
BT Donald: [Plugs cord into LabPro.]
BT Donald: Here, plug, plug that in.
Nate: [Plugs in cord.]
BT Donald: There we go.

Task 4

Nate: [Listens to JAWS.]
Nate: Does it say at 1.4 degrees? 1.4 degrees Celsius.
Partner 1: Okay, and it’s supposed to be at 0 right now because it’s like a slush mix.
JAWS: 1.6.
Partner 1: So now it’s starting to go up because all the snow is going away.
Partner 1: I’ll go grab some more real quick.
JAWS: 1.7, 1.8.
Nate: Yeah, it’s going up rapidly.

Task 5

Nate: [Works on computer.]
Nate: So what’s next after?
Partner 1: Okay, now that we got that.
Nate: It looks like we need a little ice because it’s at 1.4.
Partner 1: It doesn’t have to be perfect. Now we have to start this.

Tasks 6-7

Partner 1: Now we got to boil this water.
Nate: [Takes thermometer out of water.]
Partner 1: You gotta leave the thermometer in there, though. We can [interrupted].
Nate: Well, we’re gonna use this temperature probe.
Nate: [Puts temperature probe into the beaker.]
Nate: In there ... and then put the burner on the wood.

Task 8

Partner 1: This is boiling now.
Nate: [Enters data on computer; stops the probe reading.]
Partner 1: Do we just shut the gas off to turn it off?
Partner 1: [Turns off Bunsen burner.]
Partner 1: [Takes temperature probe out of beaker.]
Nate: Okay.
Nate: And then let’s take it, there it’s cool.
Partner 1: [Takes thermometer out of beaker.]

Task 9

Partner 1: Yeah, that’s all we’re doing today, and then for the atmospheric pressure to do our correction, it is 76 mmHg.
Nate:  76 mmHg?
Partner 1: Yeah, I don’t know what the hell that means.
Nate: [Enters information into computer.]

Investigator Commentary: In this lesson, Nate used the JAWS/Logger Pro interface. Initially, BT Donald had to assist Nate in troubleshooting the LabPro device. Once the LabPro was up and running, Nate was able to continue with the rest of the lesson without incident. Nate and his lab partner worked together on all aspects of the lab. Nate used ILAB tools and non-ILAB tools. He observed temperature changes and recorded these observations. Both Nate and his lab partner participated in the physical tasks such as pouring water and removing probes from beakers. Overall, however, the lab partner conducted more of the physical tasks, whereas Nate often recorded data as his primary function.
Lesson 4 Analysis: Solubility of an Unknown (I-Video)

Table 6-5: Lesson 4 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:36.4 - 1:19.2</td>
<td>Works on setting up computer</td>
<td>I</td>
<td>1</td>
</tr>
<tr>
<td>1:22.7 - 1:30.0</td>
<td>Looks for pencil</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>1:30.0 - 2:09.6</td>
<td>Works on computer</td>
<td>I</td>
<td>3</td>
</tr>
<tr>
<td>2:35.7 - 3:38.7</td>
<td>Works on computer</td>
<td>I</td>
<td>4</td>
</tr>
<tr>
<td>6:09.6 - 6:14.2</td>
<td>Looks through drawers for ring stand</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>6:17.5 - 6:28.6</td>
<td>Pulls ring stand out of drawer</td>
<td>N</td>
<td>6</td>
</tr>
<tr>
<td>7:25.4 - 7:31.5</td>
<td>Puts temperature probe into beaker</td>
<td>I</td>
<td>7</td>
</tr>
<tr>
<td>7:38.6 - 7:44.1</td>
<td>Works on computer</td>
<td>I</td>
<td>8</td>
</tr>
<tr>
<td>8:10.9 - 8:16.5</td>
<td>Works on computer</td>
<td>I</td>
<td>9</td>
</tr>
<tr>
<td>8:21.8 - 8:26.7</td>
<td>Moves the wire off of the balance</td>
<td>I</td>
<td>10</td>
</tr>
<tr>
<td>10:51.7 - 10:53.5</td>
<td>Puts temperature probe into the test tube containing the unknown substance</td>
<td>I</td>
<td>11</td>
</tr>
<tr>
<td>11:03.5 - 11:06.4</td>
<td>Slides test tube into clamp</td>
<td>N</td>
<td>12</td>
</tr>
<tr>
<td>11:31.9 - 11:45.8</td>
<td>Works on computer</td>
<td>I</td>
<td>13</td>
</tr>
<tr>
<td>29:48.1 - 30:06.9</td>
<td>Works on computer</td>
<td>I</td>
<td>14</td>
</tr>
<tr>
<td>35:20.3 - 37:20.6</td>
<td>Works on computer</td>
<td>N</td>
<td>15</td>
</tr>
</tbody>
</table>

Tasks 1-4

Nate: [Works on setting up computer.]
Partner 1: Nate, you got an extra pencil?
Nate: What? Yeah, I have a pencil.
Nate: [Looks for pencil.]
Nate: One pencil.
Nate: [Works on computer.]
Partner 1: [Works on papers.]
Nate: Oh, look, it’s goggles.
Nate: [Works on computer.]

Tasks 5-6

BT Donald: They’re going to set a water bath up here. That way we can use the digital thermometer and you can determine when it boils. Plug that. Beaker, let’s get a beaker. Is your ring stand up yet?
Nate: [Looks through drawers for ring stand.]
Nate: Ring stand?
Partner 1: Right there.
Nate: There she is.
Nate: [Pulls ring stand out of drawer.]
Partner 1: [Places ring stand on table.]

Tasks 7-8

BT Donald: [Places beaker on stir plate.]
BT Donald: [Adjusts ring stand.]
BT Donald: Lift up the hot plate.
Partner 1: [Moves hot plate onto ring stand base.]
BT Donald: [Adjusts ring stand.]
Partner 1: [Adjusts level on the hot plate.]
Nate: [Puts temperature probe into beaker.]
Nate: [Works on computer.]

Tasks 9-10

Nate: [Works on computer.]
Nate: Wait. 6.39. How is it 6? Oh, the wire.
Partner 1: The wire’s on that.
Nate: [Moves the wire off of the balance.]

Tasks 11-12

BT Donald: Now you’re gonna put that in your unknown.
Nate: [Puts temperature probe into the test tube containing the unknown substance.]
BT Donald: [Adjusts ring stand.]
BT Donald: [Helps Nate slide test tube into clamp.]
Nate: [Slides test tube into clamp.]
Nate: Oh, I see.
Task 13

Nate: [Works on computer.]
Nate: 0.2515.
Nate: 1.1 [inaudible].
Partner 1: Right now we’re working on boiling point for it.
Nate: It’s gone down.
Nate: I don’t think it’s supposed to be going down.
Partner 1: Well, it’s gotta heat up first.

Task 14

Nate: 82.1.
Partner 1: All right. We got a boil.
Nate: 80.9.
Nate: [Works on computer.]
Nate: What’d it say? 82.7, yeah.
Partner 1: [Removes thermometer from beaker.]
Partner 1: What was that temperature? 82.7?

Task 15

Partner 1: For the solubility, it dissolve or.... It dissolved in the water.
Partner 1: So it dissolved.
Partner 1: [Puts away papers.]
Nate: [Works on computer.]
Partner 1: [Cleans up some lab materials.]
Partner 1: [Cleans up lab bench.]

Investigator Commentary: In this lesson, Nate used a series of ILAB tools and non-ILAB tools. He was very hands-on, involved with conducting the experiment, setting up the equipment, and cleaning up. BT Donald worked with Nate’s group to ensure that the equipment was set up properly. Nate was actively involved in the data collection. He also observed a mistake and corrected it when he was working with the balance and taking a mass measurement. This demonstrated that Nate was in tune with what was happening during the experiment. Nate’s contributions were fully integrated into the group’s goal of completing the lab activity.
# Lesson 5 Analysis: Which Is Your Metal? (I-Video)

## Table 6-6: Lesson 5 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:08.8 - 0:24.4</td>
<td>Attaches temperature probe to LabPro</td>
<td>I</td>
<td>1</td>
</tr>
<tr>
<td>0:40.0 - 0:51.4</td>
<td>Works on computer</td>
<td>I</td>
<td>2</td>
</tr>
<tr>
<td>0:55.6 - 1:01.2</td>
<td>Brings wires to lab station</td>
<td>I</td>
<td>3</td>
</tr>
<tr>
<td>1:08.6 - 1:19.4</td>
<td>Plugs in LabPro</td>
<td>I</td>
<td>4</td>
</tr>
<tr>
<td>1:30.0 - 2:05.0</td>
<td>Plugs LabPro into computer</td>
<td>I</td>
<td>5</td>
</tr>
<tr>
<td>2:38.7 - 2:41.9</td>
<td>Puts metal on scale</td>
<td>I</td>
<td>6</td>
</tr>
<tr>
<td>2:51.1 - 3:31.7</td>
<td>Works on computer</td>
<td>I</td>
<td>7</td>
</tr>
<tr>
<td>3:52.2 - 4:06.6</td>
<td>Reads procedure</td>
<td>N</td>
<td>8</td>
</tr>
<tr>
<td>4:36.8 - 4:42.1</td>
<td>Brings scale over</td>
<td>N</td>
<td>9</td>
</tr>
<tr>
<td>4:49.6 - 4:54.0</td>
<td>Puts scale back</td>
<td>N</td>
<td>10</td>
</tr>
<tr>
<td>8:12.7 - 8:25.5</td>
<td>Holds ring stand</td>
<td>N</td>
<td>11</td>
</tr>
<tr>
<td>8:25.5 - 8:58.0</td>
<td>Pulls Bunsen burner out of cabinet and plugs it in</td>
<td>N</td>
<td>12</td>
</tr>
<tr>
<td>10:44.8 - 10:55.0</td>
<td>Looks for beakers</td>
<td>N</td>
<td>13</td>
</tr>
<tr>
<td>11:07.5 - 11:26.8</td>
<td>Holds beakers before putting one on table</td>
<td>N</td>
<td>14</td>
</tr>
<tr>
<td>11:28.4 - 11:37.1</td>
<td>Reads procedure</td>
<td>N</td>
<td>15</td>
</tr>
<tr>
<td>14:32.0 - 14:38.2</td>
<td>Grabs calorimeter cup and measures temperature inside with a probe</td>
<td>I</td>
<td>16</td>
</tr>
<tr>
<td>14:47.3 - 14:52.9</td>
<td>Types on BrailleNote</td>
<td>N</td>
<td>17</td>
</tr>
<tr>
<td>14:53.4 - 15:07.0</td>
<td>Checks temperature in calorimeter cup</td>
<td>I</td>
<td>18</td>
</tr>
<tr>
<td>15:11.4 - 15:13.7</td>
<td>Checks temperature again</td>
<td>I</td>
<td>19</td>
</tr>
<tr>
<td>15:49.7 - 15:50.9</td>
<td>Turns on Bunsen burner</td>
<td>N</td>
<td>20</td>
</tr>
<tr>
<td>15:56.0 - 16:05.1</td>
<td>Adjusts gas again</td>
<td>N</td>
<td>21</td>
</tr>
<tr>
<td>16:10.9 - 16:16.1</td>
<td>Places thermometer into beaker</td>
<td>I</td>
<td>22</td>
</tr>
</tbody>
</table>
Table 6-6 continued

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Activity Description</th>
<th>Match</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>21:44.9 - 21:50.2</td>
<td>Reads lab procedure</td>
<td>N</td>
<td>23</td>
</tr>
<tr>
<td>23:13.1 - 23:14.8</td>
<td>Searches drawer for other tongs</td>
<td>N</td>
<td>24</td>
</tr>
<tr>
<td>24:49.9 - 25:07.7</td>
<td>Reads thermometer</td>
<td>I</td>
<td>25</td>
</tr>
<tr>
<td>26:35.4 - 26:37.3</td>
<td>Checks temperature in calorimeter</td>
<td>I</td>
<td>26</td>
</tr>
<tr>
<td>26:40.4 - 26:48.8</td>
<td>Types on BrailleNote</td>
<td>N</td>
<td>27</td>
</tr>
<tr>
<td>26:48.9 - 27:04.3</td>
<td>Checks temperature in calorimeter</td>
<td>I</td>
<td>28</td>
</tr>
<tr>
<td>27:14.0 - 27:17.9</td>
<td>Stirs calorimeter</td>
<td>N</td>
<td>29</td>
</tr>
<tr>
<td>27:27.8 - 27:48.8</td>
<td>Holds tongs, picks up substance and drops it in beaker</td>
<td>N</td>
<td>30</td>
</tr>
</tbody>
</table>

Tasks 1-5

Nate: [Attaches temperature probe to LabPro.]
Nate: Might want to move that up, there we go.
Partner 1: So, I was, I was gone for the last lab we used this.
Nate: This is the LabPro. It’s the, um, basically the go between the probe and the computer.
Nate: [Works on computer.]
Nate: V for Vernier.
Nate: There.
Nate: [Brings wires to lab station.]
Nate: Oh, yeah, I have to plug this in first.
Nate: [Plugs LabPro into power outlet.]
Nate: [Plugs LabPro into computer.]

Tasks 6-7

Partner 1: Okay, the scale’s zeroed out now.
Nate: [Puts metal on scale.]
Nate: [Works on computer.]
Partner 1: [Adjusts scale.]
Nate: Connected, okay.
Nate: What’s it say for the mass?
Partner 1: You mean for the procedure?
Nate: Mm hmm.
Partner 1: To find the mass of the metal for the, I’m still....
**Task 8**

Nate: [Reads procedure.]
Nate: Hey, [BT Donald], was this in Braille? This procedure stuff?
BT Donald: Why? Or is that not what you’re asking?
Nate: Was this in Braille?
BT Donald: No, I had to have it Brailled. Or is that not what you’re asking?
Nate: I was saying is it in Braille?
BT Donald: No, I can’t, I couldn’t get that in Braille.

**Tasks 9-10**

Partner 1: Okay, this scale is really weird.
Nate: I’ll go get the other scale.
Nate: Oh, wait. Here’s another one closer.
Nate: [Brings scale over.]
Nate: Here’s another scale.
Partner 1: It’s like if I have it at 173 right now and it’s too high, if I put it to 174.
Nate: [Puts scale back.]

**Tasks 11-12**

Nate: [Holds ring stand.]
Nate: [Pulls Bunsen burner out of cabinet and plugs it in.]
Partner 1: Okay, I got the water.
Nate: Oh, that can’t be good.
Partner 1: We can use this to measure water. Right?
Partner 1: [Measures water with graduated cylinder.]
Partner 1: [Squirting water into the graduated cylinder.]

**Tasks 13-14**

Nate: Where’s our ...Where’s the beakers? Are the beakers in the back?
Partner 1: Um.... Yeah.
Nate: [Looks for beakers.]
Partner 1: [Helps look for beakers.]
Nate: Beakers... Where are the beakers? Well, look, beakers. What [interrupted].
BT Donald: Hey, Nate, I got one for you.
Nate: [Holds beakers before putting one on table.]
Partner 1: [Puts wool gauze on ring stand.]

**Task 15**

Nate: [Reading procedure.]
Partner 1: [Reading procedure.]
Partner 1: [Examining beaker.]
Partner 1: Umm..., I think. [BT Donald], are we supposed to put it in here first and then heat it?
Partner 1: [BT Donald], are we supposed to put it in here first and then heat it?

Tasks 16-19

Nate: [Grabs the calorimeter cup and measures the temperature of the water inside with a digital thermometer.]
Nate: So this is the initial temperature of the water ... wait, yeah.
Nate: [Types on BrailleNote.]
Nate: [Checks temperature in the calorimeter.]
Nate: It looks as if the initial temperature of the water is about 19.9. Right?
Nate: [Checks the temperature again.]
Nate: Yeah, 19.9 degrees Celsius.

Tasks 20-22

Nate: I'll turn the gas on.
Nate: [Turns on the Bunsen burner.]
Partner 1: We’re heating it with the metal in it, right?
Nate: Mm hmm. There’s the gas.
Nate: [Adjusts the gas again.]
Partner 1: [Lights the Bunsen burner.]
Nate: [Places the thermometer into the beaker.]

Task 23

Partner 1: When do we ... how do we know when to switch it?
BT Donald: Look at your procedure.
Partner 1: [Reads lab procedure.]
Nate: [Reads lab procedure.]
Partner 1: I think we [inaudible] ... it says on the Bunsen burner to heat the water to boiling. Allow the metal to remain in the boiling water for at least three minutes. Record the temperature of the boiling water.
Nate: So the boiling.
Partner 1: Using the tongs, transfer the metal from the boiling water to the calorimeter. Cover the calorimeter.
Nate: So the initial temperature of the water, I mean the metal, would have been 100 degrees Celsius. I think ..., or 100.1.

Task 24

Partner 1: Are these the tongs we’re supposed to use? They’re awful little.
Nate: [Searches drawer for other tongs.]
Nate: Are there any other tongs in here? Those must be the ones we are supposed to use if there are no other tongs in here.
Task 25

Nate: [Reads thermometer.]
Partner 1: [Stirs calorimeter.]
Nate: And I think we get it to its highest temperature that it says here, right?
Partner 1: Yup.
Nate: That’s what I thought.
Partner 1: Record the highest temperature....

Tasks 26-29

Partner 1: It hasn’t gotten any bigger, so do we want to stop it? It’s at 23.8.
Nate: [Checks the temperature in the calorimeter.]
Nate: So that would mean that the final temp is 23.8.
Partner 1: [Takes notes.]
Nate: [Types on BrailleNote.]
Nate: [Checks temperature in the calorimeter.]
Nate: [Stirs calorimeter.]

Task 30

Nate: [Holds tongs, picks up substance and drops it in the beaker.]
Partner 1: Okay. Here is the tongs. Careful!
Partner 1: [Squirts water into the beaker with the substance.]
Nate: And then ... let’s do another initial temp on water, too.

Investigator Commentary: In this lesson, Nate used a calorimeter, a Vernier temperature probe, and a balance. He was able to track the temperature and mass measurements independently. He contributed to discussions with his lab partner regarding what went on throughout the experiment. His intellectual contributions were valued by his lab partner. Nate was involved with the physical manipulations of the lab equipment, and actively participated in the reading and recording of observations. He also communicated with BT Donald on behalf of his lab group. Nate appeared to be establishing a higher level of comfort and efficacy with the ILAB tools as compared to previous lessons. However, overall, his partner contributed more time on laboratory actions than did Nate.
**Graphic Analysis of Video Data**

The data illustrated in Figures 6-1 and 6-2 show the percent of time engaged (PTE) for the BLV student and his sighted lab group partners in performing laboratory-goal-directed actions during laboratory lessons, as described in Chapter 4. This BLV student did not have more than one partner for any of the lessons included in this investigation, although sighted students may have rotated from lab to lab. Nate is indicated in blue, and the sighted partners are indicated in red. Figure 6-1 shows the results of the two lessons conducted without the use of ILAB tools, and Figure 6-2 shows the results of the three lessons conducted with ILAB tools.

Nate’s determination to stay involved in the lab activities despite not having the use of ILAB tools was observed in the N-videos. In Lesson 1, Nate exhibited 46.8% PTE while the sighted student exhibited 53.2%. While Nate had erroneously been permitted by BT Donald to use an ILAB notched syringe in Lesson 1, his time spent engaged with this tool was not included in his PTE to avoid skewing his PTE higher during the measuring of volumes than would otherwise have occurred. In Lesson 2, a make-up lab, Nate’s observed PTE was 77.5%, and the sighted student’s was 22.5%. The sighted student in this lesson appeared to have been present primarily for the purpose of observing.

Nate was somewhat less involved in two of the three lessons incorporating ILAB tools as compared to the lessons not incorporating ILAB tools. His PTEs for Lessons 3-5 were 31.3%, 75.4%, and 37.8%, respectively. The presence or non-presence of ILAB tools seemed to have had little impact on Nate’s PTE results. His overall performance was lower during the lessons with ILAB tools as compared to that during the lessons without ILAB tools.
Figure 6-1: Percent of Time Engaged During N-Video Lab Sessions for BLV Student and Sighted Partner

Figure 6-2: Percent of Time Engaged During I-Video Lab Sessions for BLV Student and Sighted Partner
Video Analysis Rubric Results

Table 6-7 shows the results of the ILAB video analysis rubric, which was designed to collect information regarding the levels of acceptance of the BLV students into their lab groups. (See the explanation in Chapter 4 and the rubric questionnaire in Table 4-5.) The three raters made numerical rankings of each of the eight rubric items for each of the five videos of Nate included in this study. The lessons conducted without ILAB tools are labeled as “N,” while the lessons conducted with ILAB tools are labeled as “I.” The three raters are identified as “EE” for the external evaluator, “IR” for the independent rater, and “IS” for the investigator in this study. For the yes/no items (A, B, E), “yes” is coded as 1 and “no” is coded as 0. For the Likert-scale items (C1-C4 and D), “strongly agree” is 5, “no opinion” is 3, and “strongly disagree” is 1.

Table 6-7: Video Analysis Rubric Results

<table>
<thead>
<tr>
<th>Rubric Item</th>
<th>Lesson 1 (N)</th>
<th>Lesson 2 (N)</th>
<th>Lesson 3 (I)</th>
<th>Lesson 4 (I)</th>
<th>Lesson 5 (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EE    IR    IS</td>
<td>EE    IR    IS</td>
<td>EE    IR    IS</td>
<td>EE    IR    IS</td>
<td>EE    IR    IS</td>
</tr>
<tr>
<td>A</td>
<td>1 1 1</td>
<td>0 1 0</td>
<td>1 1 1</td>
<td>0 1 1</td>
<td>1 1 1</td>
</tr>
<tr>
<td>B</td>
<td>1 1 1</td>
<td>0 1 1</td>
<td>1 1 1</td>
<td>0 1 1</td>
<td>1 1 1</td>
</tr>
<tr>
<td>C1</td>
<td>5 5 4</td>
<td>4 3 3</td>
<td>5 3 3</td>
<td>5 4 2</td>
<td>5 4 5</td>
</tr>
<tr>
<td>C2</td>
<td>5 5 4</td>
<td>4 4 4</td>
<td>5 2 4</td>
<td>5 4 2</td>
<td>4 4 4</td>
</tr>
<tr>
<td>C3</td>
<td>3 2 2</td>
<td>3 2 3</td>
<td>3 4 3</td>
<td>3 2 3</td>
<td>3 2 3</td>
</tr>
<tr>
<td>C4</td>
<td>1 2 1</td>
<td>1 2 2</td>
<td>1 1 3</td>
<td>1 2 4</td>
<td>1 2 2</td>
</tr>
<tr>
<td>D</td>
<td>5 5 5</td>
<td>3 4 3</td>
<td>4 4 4</td>
<td>2 4 4</td>
<td>5 4 4</td>
</tr>
<tr>
<td>E</td>
<td>1 1 1</td>
<td>0 1 0</td>
<td>1 1 1</td>
<td>1 1 1</td>
<td>1 1 1</td>
</tr>
</tbody>
</table>
Table 6-8 summarizes the patterns seen in Table 6-7, indicating the total number of occurrences found for each of the numerical rubric rankings and the averaged N vs. I scores for each rubric item. For the binary (yes/no) items, high inter-rater agreement was observed, whereas greater variability was seen in the Likert-scale ratings. This is consistent with the inter-rater reliability coefficients discussed in detail in Chapter 10.

Table 6-8: Patterns Observed with the Video Analysis Rubric

<table>
<thead>
<tr>
<th>Rubric Item</th>
<th>Summary of Scores</th>
<th>Average N</th>
<th>Average I</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>12 ones of 15 possible</td>
<td>0.67</td>
<td>0.89</td>
</tr>
<tr>
<td>B</td>
<td>13 ones of 15 possible</td>
<td>0.83</td>
<td>0.89</td>
</tr>
<tr>
<td>C1</td>
<td>6 fives, 4 fours, 4 threes, 1 two</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>C2</td>
<td>4 fives, 9 fours, 2 twos</td>
<td>4.3</td>
<td>3.8</td>
</tr>
<tr>
<td>C3</td>
<td>1 four, 9 threes, 5 twos</td>
<td>2.5</td>
<td>2.9</td>
</tr>
<tr>
<td>C4</td>
<td>1 four, 1 three, 6 twos, 7 ones</td>
<td>1.5</td>
<td>1.9</td>
</tr>
<tr>
<td>D</td>
<td>4 fives, 8 fours, 2 threes, 1 two</td>
<td>4.2</td>
<td>3.9</td>
</tr>
<tr>
<td>E</td>
<td>13 ones of 15 possible</td>
<td>0.67</td>
<td>1.0</td>
</tr>
</tbody>
</table>

For items A, B, and E, the raters generally agreed that the BLV student was significantly involved in discussions related to the completion of the laboratory goal, that the sighted students accepted the contributions of the BLV student, and that the BLV student was included in the collaborative participation of the group, respectively. In comparing the N-lessons to the I-lessons for these three rubric items, it can be seen that the rankings are higher for the I-lessons than for the N-lessons, indicating an improvement during the lessons incorporating ILAB tools, with the greatest improvement being observed in item E.

In the case of C1, the average of the rater scores was toward the higher end of the scale, indicating that the BLV student exhibited high overall interest in the lessons, with
no change being noted from the N-lessons to the I-lessons. However, Lessons 3 and 4 for item C1 exhibited substantial variations in rankings, with scores ranging from 3 to 5 for Lesson 3 and 2 to 5 for Lesson 4. In C2, the averaged rankings indicate that the BLV student’s level of interest stayed much the same throughout the lessons, although more so for the N-lessons than for the I-lessons. Again, there was substantial disagreement between the raters for Lessons 3 and 4, with scores ranging from 2 to 5 in each of those lessons. For C3, which asks whether the level of interest of the BLV student increased during the experiments as a result of comprehension, the averaged rankings indicate mild disagreement with this statement, meaning that the BLV student’s interest likely did not increase, although scores were slightly higher for the I-lessons as compared to the N-lessons. For Item C4, which asks whether the level of interest of the BLV student decreased during the experiments as a result of losing interest, the averaged rankings show that the BLV student’s interest likely did not decrease during either the N-lessons or the I-lessons. However, substantial rater disagreement was seen in item C4 for Lessons 3 and 4, with rankings in Lesson 3 ranging from 1 to 3 and from 1 to 4 in Lesson 4.

For item D, the raters generally exhibited high agreement except for Lesson 4, which had rankings ranging from 2 to 4. In general, the raters felt that the techniques used by the BLV student were perceived by sighted lab partners as being beneficial, although the averaged N score was slightly higher than the averaged I score, which is not the preferred result.

None of the lessons had complete agreement across all rubric items. Rater disagreements of only one level within individual Likert-scale rubric items may have been due to small variations in interpretation and/or perception, whereas disagreements of
greater than one level may have been caused by unintentionally ambiguous terminology in the rubric itself, as discussed in Chapter 10.

**Summary**

Nate was substantially involved in all lessons both with and without ILAB tools but exhibited better overall PTE in the non-ILAB lessons. He was able to compensate for his BLV status with good communication skills and residual vision. He used his residual vision to assist in reading volumes on graduated cylinders and with other lab equipment, allowing him to participate more in the non-ILAB lessons than if he had been completely blind. Nate also tended to take plenty of preparation time for lessons, likewise favorably impacting his ability to participate.

Nate expressed excitement in his pre- and post-year interviews and exhibited a slight increase in positivity in his already-positive attitude toward science, as evidenced by his SAI II results. He valued his participation in the ILAB study and was very self-motivated in learning to use the JAWS/Logger Pro interface. He also practiced using the various ILAB tools such as the SALS sensor. Nate received minimal help from BT Donald during lab sessions. He demonstrated efficacy with the JAWS/Logger Pro interface and other ILAB tools. Nate exhibited a commitment to learning how to use the ILAB tools and transferred that knowledge to his classroom experiences. However, Nate’s video analysis rubric scores indicated mixed results, with improvement during the ILAB lessons for some of the rubric items but not for others.

Nate used a computer equipped with JAWS to read lab procedures both for ILAB lessons and non-ILAB lessons. His computer skills were superior to those of most blind
students, as demonstrated by his high usage and speed of comprehension of the JAWS synthetic speech. This was probably due to many years of extensive experience in using JAWS.

In general, Nate worked well with his lab partners. His strong communication skills aided him in group discussions, in many instances allowing him to influence group decisions.
Chapter 7

Highland Hills High School Case Study

Highland Hills High School (a pseudonym) is located in a suburb of a major metropolitan area in a Mid-Atlantic state on the Eastern seaboard of the United States. The town’s population is comprised predominantly of middle- and upper-class families. It is the goal of the science department at the school to prepare students for the challenges of tomorrow through understanding science and technology.

Demographics of School

Highland Hills has a student body of approximately 1,000 individuals, with 50% male and 50% female. At the time of this study, the school had 15 science faculty members, with a number of them having advanced science or education degrees. Reported student racial background was white 89%, Asian 6%, African-American 2%, Hispanic 2%, and Native American 1%.

Background of Student

The student from Highland Hills was given the pseudonym of Ryan. He was an 18-year-old senior enrolled in advanced placement (AP) physics. He indicated he could not see much of anything. Occasionally, he sees random colors but says they are not meaningful, and that distance vision is not really possible. He is unable to perceive objects, but can tell if the lights are on or off. Ryan indicated an interest in engineering as a possible career path after high school. His previous lab classes included honors
chemistry, AP chemistry, biology, and regular physics. Ryan wanted to make himself useful in whatever ways he could in lab classes. Previously, lab partners had described what went on during lab activities, but he had not found these experiences to be compelling.

Ryan had used the ILAB tools in his previous chemistry classes and found them beneficial in increasing his ability to participate during labs. He used a laptop computer in conjunction with the ILAB tools. Academically, Ryan was in the top 5% of his class and indicated that science had always come easy to him. Typically, he had worked with either one or two lab partners. While Ryan tended to work with the same partner from lesson to lesson, the teacher occasionally had him work with other students as well.

**Background of Teacher**

The AP physics teacher at Highland Hills was given the pseudonym of HT April (Highland teacher April). In addition to AP physics, she taught honors and regular physics classes. She said the College Board required that, for the year of the study, AP classes have 20% of the curriculum be lab lessons. She used the guided-inquiry approach for her lab activities and taught the class by supplementing labs with the necessary math skills for solving the problems. She would often put a physics problem on the board and have students design their own experiments to test the theory being questioned. This approach was similar to that discussed in Palincsar et al. (2001), who stated that recent science reforms recommended students engage in inquiry-based learning. HT April left it to the students to ask for help when needed and to figure out how to conduct experiments. The AP physics class had 18 students, 14 of whom were male.
Classroom Resources

HT April had access to a physics classroom equipped with work tables for conducting lab activities. The classroom also had standard desks for students to use during lecture periods, as well as a number of PC computers for student use. HT April had a number of Pasco laboratory probes available along with the DataStudio data collection software package. The investigator provided HT April with a complete set of Vernier Software & Technology physics probes for Ryan to use instead of the Pasco probes. Students also had access to voltage probes and various hand tools such as pliers, screwdrivers, and hammers to aid in conducting experiments, along with an assortment of carts, tracks, pulleys, and other physics mechanics equipment.

Class periods were 90 minutes in length. The AP physics course lasted the entire school year. HT April was readily available for questions from the students while they conducted experiments. A Braille textbook was provided to Ryan; homework assignments and handouts related to the labs were given to him in electronic format on a thumb drive. Ryan used his own laptop equipped with JAWS to read lab instructions. He also used the laptop as his primary note-taking tool during labs and lectures.

Relationship between Investigator, Teacher, BLV Student, and Parents

The investigator worked directly with HT April regarding laboratory adaptations. A detailed training workshop was held prior to the school year to familiarize her and Ryan with the ILAB tools and their functions. As part of training, several physics lab exercises from a different AP curriculum were conducted, giving Ryan the opportunity to use the Vernier physics probes for the first time. Later, there were many email
communications between the investigator and teacher regarding how things had gone
during each lab activity. HT April also participated in ILAB team conference calls every
60 days, giving her the opportunity to share her experiences as well as learn from other
teachers participating in the ILAB study. Overall, teacher/investigator interactions were
very positive. Ryan had a very hands-on science laboratory learning experience as a
result of his teacher’s high enthusiasm for the ILAB project.

Ryan emailed the investigator from time to time with feedback on how the ILAB
tools were working and offered suggestions for improvements. A number of his
suggestions were shared with Vernier software engineers and later incorporated into the
JAWS/Logger Pro programming scripts.

Very little communication with Ryan’s parents took place, although his father
made sure Ryan attended all ILAB training sessions.

**Interview Data**

The following are excerpts and/or summaries of dialogue between the investigator
and the BLV student, and between the investigator and the teacher. The questions asked
were based on the standard interview scripts for the ILAB study (Tables 4-1, 4-2, 4-3); follow-up questions for clarification were also asked, dependent on the student’s or
teacher’s responses to the initial queries. These particular questions were chosen for
analysis because of their significance to the incorporation of the BLV student into lab
groups, his efficacy with the ILAB tools, and his interest in science. Commentary from
the investigator follows the excerpts/summaries for each interview.
Excerpts, Summaries, Commentary: Pre-School-Year Student Interview

Up until this point, have you taken any mainstream science classes? Did any of them have a lab component?

Ryan indicated he had taken honors chemistry, AP chemistry, regular physics, biology, and various math classes. All the science classes included laboratory components.

How would you rate those particular laboratory experiences?

“People would describe what was going on and I made myself useful in whatever way was possible. It was okay, but not particularly interesting.”

Investigator Commentary: Ryan expressed a willingness to participate in laboratory classes and a desire to be as useful to his lab groups as possible. He is more academically developed than most of his peers and exhibited strong interest in science based on his having enrolled in AP physics. Ryan had been exposed to ILAB tools over the previous two years of high school, thus his lab skills were well developed. He indicated no apprehension of any kind toward his upcoming AP physics class.

Excerpts, Summaries, Commentary: Post-School-Year Student Interview

What was your favorite part of physics class this year?

Ryan indicated that he most enjoyed the problem-solving aspects of his physics class due to the challenges posed by the laboratories.
Did you like the laboratory part of the physics class?
He said he found the labs interesting and enjoyable because he had been able to work on exploring problems with a group of other students.

Do you think your visual impairment made working in the laboratory more difficult?
“Having a visual impairment means there are certain methods of doing things that are not available. Sometimes these methods are sometimes truly the easiest methods of getting something done. So to some degree, yes, it makes things more difficult.”

What kinds of tasks did you work on in the lab? Did you work on some of everything, or did you end up working on things you knew you could do?
“I worked on most of the aspects of things.”

Do you think this class helped you to realize that you could do science and that it wouldn’t be too hard for you?
“I think it helped me to realize the interesting parts of science but I don’t think it helped move me in the direction that science wasn’t too hard.”

Investigator Commentary: Ryan expressed a strong enjoyment for problem solving; this is a key attribute in an AP physics class. He indicated the class was very simple for him. He was able to successfully work with others in his lab groups. The lab component of this physics course was very enjoyable for him because of the guided-inquiry approach to hands-on laboratory learning making problem solving the centerpiece of each experiment. Overall, Ryan had a positive learning experience during the laboratory component of this class.
**Excerpts, Summaries, Commentary: Post-School-Year Teacher Interview**

*Did the student remain in his comfort zone or did he actively participate in the sharing of all of the tasks in the lab?*

“[Ryan and his partner] work well together. I didn’t ever recall one of them monopolizing a particular task. They’re both very gung-ho and ‘Hey, let’s try this,’ ‘No, that’s not going to work, let’s try my idea.’”

*How well do you think Ryan was able to function in the lab group?*

“As well as any member of any other team.... Ryan and his partner enjoy each other’s company. They value each other’s ideas. They work very well together, probably better than any of the other teams in the class.”

*Did you observe an increase in Ryan’s self efficacy with the tools as the year progressed?*

“He was pretty well versed in how to use stuff at the beginning of the year, but some of the tools were ones he had not used before. We were all a little bit confused about the talking voltmeter. And where to plug stuff in, but it didn’t take him long to figure that out.”

*Did he work well with the rest of the students?*

“Ryan has been speaking more lately than he did at the beginning of the year, which I think is good. He has a lot of really good insights to share. I think that there are a number of kids in class who really respect Ryan’s ideas. There are also about six boys who don’t respect anyone’s ideas. So I don’t know if that had anything to do with his silence initially.”
How would you say that Ryan’s visual impairment affected his ability to function in the AP physics class as a whole?

“On tests he is consistently one of the top two performers.... They don’t always follow through on written work though, so they’re not necessarily the highest grade for the quarter, but in terms of making sense of concepts, connecting theory to math and problem-solving ability, they are fabulous.”

Investigator Commentary: HT April indicated Ryan worked well with his lab partner in this physics class. He is highly respected by his classmates. Ryan also worked well with the ILAB tools provided to him. He has a strong drive for conducting lab experiments, which may be due to his previous experiences with ILAB tools. A few trouble spots did occur with some of the ILAB tool interventions but, all in all, he did fine with tool implementation. From HT April’s perspective, Ryan exhibited comfort with all ILAB tools throughout the course.

SAI II Survey Data Pre/Post School Year

Ryan’s SAI II survey data appear in Table 7-1. The table indicates the six attitudinal constructs, as discussed in Chapter 4. The Likert score totals for each construct are from the 40 questions in the SAI II instrument (see Table 4-4 in Chapter 4), with positive questions categorized as “A” and negative questions categorized as “B.” The “B” questions were reverse-coded for point values, meaning that higher scores indicate better attitudes both for the “A” and “B” questions, as described in Chapter 4. At the bottom of the table are total shifts in attitude for all “A” items and all “B” items, and a total for “A” and “B” together.
Ryan exhibited a substantial improvement in attitude toward science from the pre-
school-year survey to the post-school-year survey, as illustrated by his increase in “all
AB” score of 11 points. His overall attitude toward science was quite high even before
participating in the ILAB study; his participation appears to have further strengthened his
positivity toward science. This is evident in his “all A,” “all B,” and “all AB” scores. The
greatest impact was for construct #2, with an increase of 9 points. Increases of 1 point
each were seen in constructs #1, #4, and #6. No change was seen for construct #5, and
construct #3 had a 1-point decline.
Table 7-1: SAI II Data for Ryan, Pre/Post School Year 2007-08

<table>
<thead>
<tr>
<th>Attitudinal Construct Scores</th>
<th>Pre-Year</th>
<th>Post-Year</th>
<th>Difference Pre/Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-A</td>
<td>15</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>1-B</td>
<td>8</td>
<td>9</td>
<td>+1</td>
</tr>
<tr>
<td>2-A</td>
<td>7</td>
<td>13</td>
<td>+6</td>
</tr>
<tr>
<td>2-B</td>
<td>9</td>
<td>12</td>
<td>+3</td>
</tr>
<tr>
<td>3-A</td>
<td>15</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>3-B</td>
<td>15</td>
<td>14</td>
<td>-1</td>
</tr>
<tr>
<td>4-A</td>
<td>9</td>
<td>11</td>
<td>+2</td>
</tr>
<tr>
<td>4-B</td>
<td>7</td>
<td>6</td>
<td>-1</td>
</tr>
<tr>
<td>5-A</td>
<td>14</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>5-B</td>
<td>14</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>6-A</td>
<td>21</td>
<td>20</td>
<td>-1</td>
</tr>
<tr>
<td>6-B</td>
<td>22</td>
<td>24</td>
<td>+2</td>
</tr>
<tr>
<td>All A</td>
<td>81</td>
<td>88</td>
<td>+7</td>
</tr>
<tr>
<td>All B</td>
<td>75</td>
<td>79</td>
<td>+4</td>
</tr>
<tr>
<td>All AB</td>
<td>156</td>
<td>167</td>
<td>+11</td>
</tr>
</tbody>
</table>
Overview of the Five Laboratory Lessons

This section contains synopses of what occurred in each of the five audio-video-recorded laboratory lessons. The lessons were part of the school’s regular curriculum. The following descriptions were written from the lesson transcripts. The synopses are not intended as complete representations of activities during each lesson, but rather are intended to provide readers with an idea of what the BLV student experienced. Short descriptions regarding how the BLV student interacted with his group partners are also included. Lab groups varied in size from lesson to lesson, comprising two or more people. Only the lab partners with whom Ryan had the most communications and interactions are noted in the following synopses.

Please note that while the lessons not incorporating the ILAB tools are listed first, they did not necessarily precede the lessons with ILAB tools chronologically. However, the two N-lessons are chronological in relationship to each other, as are the three I-lessons. The I-lessons are listed in the order in which they actually occurred to better illustrate the BLV student’s progress, if any.

Lesson 1 Synopsis: Balance (N-Video)

First, Ryan and his partner determined the balance point of a meter stick by taping and balancing weights on it; they put the fulcrum near the 25 cm mark. The partner explained to Ryan that the position of the mass was important for data collection. Then they weighed a new mass to balance another mass on the opposite end of the meter stick. HT April offered the suggestion of trying to balance the meter stick on a single point. Ryan said he believed doing so would yield less accurate results but that the set up would
likely be more stable. Ryan and his partner explored using various arrangements of the weights and the meter stick to achieve the most accurate placement. They performed calculations and recorded the data.

**Lesson 2 Synopsis: Speaker (N-Video)**

In the beginning, Ryan’s partner tried to hypothesize how speaker volume would change with altered terms in the equation. Ryan and his partner tried to figure out how energy stored in the inductor was related as a function of the B-field, power, intensity, and EMF. They analyzed the situation to understand how much energy was going back to the circuit and how much was vibrating the cup. Ryan’s partner suggested putting the speaker near their ears to assess the volume, but Ryan said doing so would be inaccurate and the theoretical model they had proposed would not work. Ryan suggested increasing the number of coils and then testing the volume. His partner placed the speaker near the noise source with the B-field directed toward the solenoid, and told Ryan to listen to the speaker and rank the loudness while he varied the terms. They decided to change the variable to 10, 15, 20, 25, and 30. Ryan’s partner commented that the independent variable would be the number of turns, and the dependent variable would be the perceived loudness between 1 and 10. They discussed variables, constants, and a randomness coefficient. They tried to analyze the equation while working with the coils. Ryan’s partner sanded the ends of the wires while Ryan worked on his computer, then Ryan sanded the ends of the wires. HT April offered to let Ryan use some of the larger magnets. Ryan attached alligator clips to the wire leads in the cup; his partner readjusted the clips for better contact. The OMI device read a large resistance, so Ryan suggested
attaching the OMI meter between the alligator clips to establish a smaller resistance value. Ryan and his partner tried to set up the speaker to discover if any sound would be produced by the device. HT April suggested using a coil with a smaller diameter. A co-teacher suggested using more coils around the marker, which Ryan and his partner attempted to do. Ryan volunteered to coil the wire while his partner held it up. They held the speaker against their ears and claimed to hear some sounds. Ryan and his partner both participated very actively in this experiment, troubleshooting the equipment together and exchanging ideas effectively.

**Lesson 3 Synopsis: Bull’s-Eye (I-Video)**

Ryan helped set up the equipment for the experiment. Ryan and his partners tried to calculate the velocity of the x-component. Ryan measured the distance of the ramp and dropped the ball down the ramp, while HT April caught the ball. Ryan’s partners assisted him by recording important data. HT April explained to Ryan that he could specify on his data sheet where the ramp was placed and where the ball could roll down. Ryan and his partners compared the velocities and obtained similar results. He explained to his lab partners that the time could be measured using the motion sensor to give more accurate results than those from manual timing using a stopwatch.

**Lesson 4 Synopsis: Falling Mass Cars (I-Video)**

Ryan took down some data at the beginning and set up the cars. His partner recorded some data. Ryan’s lab partner was unsure about the unknown masses; HT April suggested comparing their sizes with each other to figure out the relative masses, with the
largest being 100, then decreasing to 50, 20, 10, and 5. HT April explained to the students to use three different masses and a control for their experimental setup. Ryan’s partner asked Ryan to start collecting data at the point when the partner was to let go of the car with the mass. Ryan agreed. On their second trial, they tried to start collecting data before letting go of the car. They used a smaller mass on their next setup because their car initially had a high velocity, showing some kind of error in their data. Ryan and his partner exchanged duties, with the partner collecting the data and Ryan working with the car. Ryan and his partner agreed to use the data for the lower masses, and set up another trial. During this trial, an error message appeared when they attempted to start collecting the data. Ryan and his partner tried to troubleshoot the equipment and rebooted the computer. They successfully collected all the data they needed for the experiment.

**Lesson 5 Synopsis: Pendulum (I-Video)**

Ryan’s lab partner taped the motion sensor probe to the table and plugged the probe into the power. Ryan suggested using a 50-gram weight with a 5-gram hanger. Ryan’s partner added the weight to the spring, and Ryan examined the springs on the table. The partner suggested dragging the spring at an incline to 10 cm, but Ryan said problems could occur with their setup at the recommended incline. Ryan placed the weight on the pendulum while his partner assisted by measuring the spring with a meter stick. Ryan then worked on his computer while his partner adjusted the pendulum. Different springs were tried. Ryan pulled on the pendulum; then his partner pulled on the pendulum, causing the spring to come loose. The partner fixed the pendulum and the spring. Ryan and his partner analyzed the provided data to match it with the behavior of
the pendulum. Throughout the experiment, Ryan offered much input on the theory of the pendulum’s behavior and actively participated in setting up and troubleshooting the equipment.

**Video Task Analysis for Each Lesson**

The following five tables (7-2 through 7-6) were constructed to classify the types of tasks performed by Ryan within each lesson. Excerpts from the transcripts of the corresponding lab group actions and dialogue are included following each table. The time stamp for each task, a description of the task performed, whether or not the task involved ILAB tools, and the task number (assigned consecutively for each chronological, discrete task that appears in each table, indicated so as to relate individual tasks in the tables to the appropriate transcript excerpts) are shown. (Note: Sometimes working on the computer is categorized as an ILAB-tool task and sometimes as a non-ILAB-tool task; the selection of “I” or “N” was based on whether the computer was being used along with an ILAB tool to take a data point or simply to take notes or perform calculations.) As stated in Chapter 4, not all actions in the video task analysis were necessarily directed toward laboratory goals.

The selected tasks are not inclusive but were chosen as illustrative to provide an overview of the types of tasks and dialogue that occurred within each lesson. Lab groups varied in size from lesson to lesson, comprising two or more people. Only the lab partners with whom Ryan had the most communications and interactions are noted in the following tables and excerpts.
Lesson 1 Analysis: Balance (N-Video)

Table 7-2: Lesson 1 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:49.7 - 1:48.7</td>
<td>Setting up experiment</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>2:00.0 - 2:07.0</td>
<td>Balancing weights on meter stick</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>2:10.3 - 2:22.7</td>
<td>Balancing weights on meter stick</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>2:32.5 - 2:57.1</td>
<td>Balancing weights on meter stick</td>
<td>N</td>
<td>4</td>
</tr>
<tr>
<td>3:06.8 - 3:53.1</td>
<td>Setting up next trial</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>7:11.2 - 7:30.4</td>
<td>Balancing weight on meter stick</td>
<td>N</td>
<td>6</td>
</tr>
<tr>
<td>9:55.3 - 11:37.3</td>
<td>Cleaning up</td>
<td>N</td>
<td>7</td>
</tr>
</tbody>
</table>

Task 1

HT April: So today is the 13th of November, this is the Balance Lab.
Ryan: [Setting up experiment.]
Ryan: This has to go where? Right about there?
Partner 1: Oh, that one? Yes, it wants to go right about there.

Tasks 2-4

Ryan: This is the balance point, right there?
Ryan: Which thing, do you think, is the 50 cm mark?
Ryan: Which side of the tape is the 50 cm mark?
Partner 1: Oh, the, this side.
Ryan: This side, okay.
Partner 1: Yes.
Partner 1: Fifteen cm would be right about here.
Partner 1: I’d say it’s close to balance.
Ryan: [Balancing weights on meter stick.]
Partner 1: Can you like switch it a little bit?
Ryan: [Balancing weights on meter stick.]
Partner 1: You know what it seems?
Partner 1: Well, it was tilted to one way, then if you push it the other way and it tilts the other way, which way it tends to turn...
Ryan: [Balancing weights on meter stick.]

Task 5

Partner 1: [Reading from procedure.] All right, move the fulcrum point so that it is 25 cm from one end of the stick.
Ryan: So that it’s 25 cm from the one end of the stick?
Ryan: [Setting up next trial.]

Task 6

Ryan: Like, essentially it’s at like 2 or 3 cm, right?
Partner 1: From the end?
Ryan: Yeah.
Partner 1: Yeah, it’s around the 5 mark.
Ryan: [Balancing weight on the meter stick.]
Partner 1: So do you want to say 5?
Ryan: You want to try to make it more accurate than that?
Partner 1: What?
Ryan: You want to try to get it more accurate than that?
Partner 1: I think, just go with 5, maybe 5 and a half.
Ryan: 5.5 cm from the end.

Task 7

Partner 1: So you clean up the other stuff, just take it over to the balance.
Partner 1: [Cleaning up.]
Ryan: [Cleaning up.]

Investigator Commentary: In this lesson, Ryan participated both physically and verbally. He was active in the discussions of equipment set up, running the experiment, and cleaning up. He had been known in the past to exhibit some hesitation to participate in discussions, but significantly verbally contributed to this experiment when he felt he had something to add and was involved in the intellectual discussions of each trial. He was fully engaged in the experiment, and contributed more time engaged in lab actions than did his partner, both hands-on and verbally.
Lesson 2 Analysis: Speaker (N-Video)

Table 7-3: Lesson 2 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:40.9 - 8:47.0</td>
<td>Working on computer</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>15:02.7 - 15:55.1</td>
<td>Rolls wire around marker</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>15:38.0 - 15:54.5</td>
<td>Counting coils</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>16:17.4 - 16:27.5</td>
<td>Working with wire</td>
<td>N</td>
<td>4</td>
</tr>
<tr>
<td>16:28.2 - 17:02.2</td>
<td>Working with wire</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>17:21.4 - 17:36.4</td>
<td>Working with magnets</td>
<td>N</td>
<td>6</td>
</tr>
<tr>
<td>18:03.4 - 18:26.9</td>
<td>Working with wire</td>
<td>N</td>
<td>7</td>
</tr>
<tr>
<td>23:46.6 - 24:31.0</td>
<td>Sanding the ends of the wires</td>
<td>N</td>
<td>8</td>
</tr>
<tr>
<td>25:25.9 - 26:02.8</td>
<td>Holding wire to voltmeter</td>
<td>N</td>
<td>9</td>
</tr>
<tr>
<td>26:28.9 - 26:51.1</td>
<td>Connecting alligator clips to wires on cup</td>
<td>N</td>
<td>10</td>
</tr>
<tr>
<td>28:54.7 - 29:04.8</td>
<td>Hitting keys on keyboard</td>
<td>N</td>
<td>11</td>
</tr>
<tr>
<td>29:08.0 - 29:21.7</td>
<td>Hitting keys on keyboard</td>
<td>N</td>
<td>12</td>
</tr>
<tr>
<td>34:04.4 - 34:18.1</td>
<td>Unraveling coils off of marker</td>
<td>N</td>
<td>13</td>
</tr>
<tr>
<td>37:33.2 - 39:02.5</td>
<td>Typing on computer</td>
<td>N</td>
<td>14</td>
</tr>
<tr>
<td>38:20.1 - 38:45.8</td>
<td>Holding wire up</td>
<td>N</td>
<td>15</td>
</tr>
<tr>
<td>39:30.6 - 39:44.0</td>
<td>Listening into cup</td>
<td>N</td>
<td>16</td>
</tr>
<tr>
<td>40:35.0 - 40:53.5</td>
<td>Cleaning up</td>
<td>N</td>
<td>17</td>
</tr>
</tbody>
</table>

Task 1

Ryan: Yeah, so building a speaker. Then I imagine what I would do is test the volume, increase the number of coils, test the volume again, increase the number of coils again, test the volume, and increase the coils a few times, and test the volume.
Partner 1: Okay, so, what we do is we hook it up to, are we going to use your computer as the thing source or something else?
Ryan: Whatever you want to use. I don’t care.
Partner 1: Um.
Partner 1: [Makes notes.]
Ryan: [Working on computer.]

Task 2

Partner 1: So, how much of this are we going to need?
Partner 1: Start by rolling 30 turns of it onto a marker.
Ryan: Okay, marker.
Partner 1: And that way we’ll know how much.
Ryan: Okay.
Ryan: [Rolls wire around marker.]
Partner 1: And then we can cut it and do that thing.
Partner 1: Because we have to unwind later.

Task 3

HT April: Did I give you magnets?
HT April: No, I need to get you magnets. That’s right.
Ryan: Can you hold the wire up above?
Partner 1: Uh, sure.
Partner 1: [Holds up wire.]
Ryan: [Counting coils.]
Partner 1: Why don’t you just do a few more? That way we don’t end up short in the end.
Ryan: Okay.
Partner 1: All right, that’s good.

Tasks 4-5

Ryan: [Working with wire.]
Ryan: How are you supposed to bend wires?
Partner 1: Bend it and bend it and bend it. Maybe the wire’s too strong. Oh, you got it, okay.
Partner 1: [Working with wire.]
Ryan: [Working with wire.]

Task 6

Ryan: Do we have something to strip with?
Ryan: [Feels around table.]
Partner 1: Um, sandpaper? No, I’ll get some.
Ryan: Doesn’t stripping with sandpaper seem slightly strange to you?
Partner 1: It’s something I’ve never done before.
Partner 1: [Gets sandpaper.]
Ryan: [Working with magnets.]

**Task 7**

Partner 1: Okay, I have a little bunched up bit right here to put over it. But I don’t know how many turns it is, so you might want to count that.
Ryan: Honestly, I’m thinking I’m going to go uncoil ... okay?
Ryan: [Working with wire.]
Ryan: Yeah, I’m going to go back to my way of coiling, okay? Because I think it’s easier.
Partner 1: Yes, I think you’re right.

**Task 8**

HT April: What are you doing?
Ryan: [Sanding the ends of the wire.]
Ryan: I am attempting to sand [interrupted].
HT April: Oh, the shellac off the wire, okay.
Ryan: Because apparently the wire stripper hasn’t been invented yet.

**Task 9**

Partner 1: Yeah, the resistance was bad. Can you, can you hold the short wire to the thing? Cause I can’t hold it there.
Ryan: [Holding wire to voltmeter.]

**Task 10**

Ryan: [Connecting alligator clips to wires on cup.]
Ryan: Yes.
Ryan: Because we felt we needed an uber long lead.
Partner 1: So do you think you got a good spot?
Ryan: Uh, darned if I know.
Partner 1: All right, uh, here’s the, uh...
Partner 1: [Testing resistance.]
Partner 1: The OMI thingy doesn’t think he got a good contact.
Ryan: Okay, should I just retry it?
Partner 1: Sure.
Partner 1: Just let me slide it around on the alligator a bit, see if we can get a [interrupted].
Ryan: Now what does the OMI thing think?
Partner 1: Still says infinite resistance, looks better toward the end of the wire.
**Tasks 11-12**

Partner 1: Here can you play some noise on your computer?
Partner 1: [Listening into cup.]
Ryan: [Hitting keys on keyboard.]
Ryan: I thoroughly corrupted a file if anything is open.
Partner 1: Keep typing some more, I wanna see what...
Ryan: [Hitting keys on keyboard.]
HT April: Do you think anybody else is hearing anything?
Partner 1: The noise of your typing is drowning it out.

**Task 13**

Partner 1: See, you’re losing loops, they’re falling off the end.
Ryan: [Unraveling coils off of marker.]
Ryan: Yeah, they’re falling off, and the other thing is that it got, it got overwrapped so I can’t feed it in to the very end.
Partner 1: So you’re just going to unwind the whole thing?
Ryan: Um, I don’t ...
Ryan: Cause if you do anything more than 10, a lot more noise, you know it works, right?
Partner 1: I suppose.
Partner 1: Let’s try to take this off without mutilating it.

**Tasks 14-15**

Ryan: [Typing on computer.]
Ryan: Oh.
Partner 1: [Listening into cup.]
Ryan: Are you hearing anything there?
Partner 1: I haven’t got it positioned right. Do you have the volume up all the way?
Ryan: I believe so.
Partner 1: Can you like play music or anything, or do you just got like text sorta sounds?
Ryan: Um, I don’t know where music would be, if I ...
Partner 1: All right, well, just play whatever.
Partner 1: Can you, um, well, if you have a free hand, can you hold the wire up so it’s out of the way?
Ryan: Mmm hmm.
Partner 1: Thanks.
Ryan: [Holding wire up.]

**Task 16**

Partner 1: You playing the noise?
Ryan: Yeah.
Ryan: Let me see.
Partner 1: I’m not, I’m not hearing.
Ryan: [Listening into cup.]
Ryan: Yeah, I mean hold it really against your ear, it’s [interrupted].
Partner 1: All right, let me try again, it’s probably something. What are you playing?
Ryan: I think it’s like [interrupted].
Partner 1: I heard it!

Task 17

HT April: Okay, great, and you got something?
Partner 1: [Cleaning up.]
Ryan: [Cleaning up.]
Partner 1: Yes.
HT April: Fabulous, fabulous.

Investigator Commentary: Ryan’s sarcasm toward HT April and his lab partner helped illustrate his involvement in the group, in that he felt comfortable and confident enough to be sarcastic. He was very involved in the hands-on aspects of equipment setup and manipulations. He was also directly involved in listening for sound from the speaker they were constructing. His attempts to use his computer to make noise and listen for output from the speaker showed his understanding of the experiment, and he even corrected his partner’s technique in listening. Ryan used his computer for recording observations, and worked with JAWS, Microsoft Word, and Excel.
Lesson 3 Analysis: Bull’s-Eye (I-Video)

Table 7-4: Lesson 3 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:28.1 - 9:33.6</td>
<td>Moves ball along ramp</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>11:16.0 - 11:17.8</td>
<td>Drops ball down ramp</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>11:34.7 - 11:47.9</td>
<td>Measures distance</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>12:22.2 - 12:23.8</td>
<td>Measures distance</td>
<td>N</td>
<td>4</td>
</tr>
<tr>
<td>14:04.9 - 14:05.9</td>
<td>Drops ball down ramp</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>14:28.2 - 14:29.2</td>
<td>Drops ball down ramp</td>
<td>N</td>
<td>6</td>
</tr>
<tr>
<td>14:41.1 - 14:47.2</td>
<td>Drops ball down ramp</td>
<td>N</td>
<td>7</td>
</tr>
<tr>
<td>15:08.5 - 15:09.5</td>
<td>Drops ball down ramp</td>
<td>N</td>
<td>8</td>
</tr>
<tr>
<td>16:38.9 - 18:26.1</td>
<td>Works with data</td>
<td>N</td>
<td>9</td>
</tr>
<tr>
<td>18:35.2 - 19:34.0</td>
<td>Works with data</td>
<td>N</td>
<td>10</td>
</tr>
</tbody>
</table>

**Task 1**

Partner 1: Okay, what we’re going to do, it’s going to roll down the ramp and then it will [interrupted].
Ryan: Wait, wait.
Ryan: Yeah, but the question is ... going ... fast.
Partner 1: You have to do it up here when it first rolls off. We’re going to assume that’s the velocity.
Ryan: [Moves ball along ramp.]

**Task 2**

Partner 1: Okay, so I start timing as soon as it’s at the bottom of there.
Ryan: Yeah.
HT April: Here. I’ll catch it.
Ryan: [Drops ball down ramp.]
Partner 1: I got 0.25 seconds.
Ryan: Okay, let’s move it back.
**Tasks 3-4**

Partner 1: I’m going to get some tape to tape the ramp so ...  
Ryan: I think I remember doing like this, five meters.  
Ryan: This thing ...  
Ryan: [Measures distance.]  
Partner 1: Stop it like right here or ...  
Partner 1: Too much space.  
Ryan: If we’re not there ...  
Ryan: So what was the ... again? Let’s just test to see that this does ...  
Partner 1: Okay. I don’t know. We probably actually should have ... I think that’s pretty good.  
Ryan: [Measures distance.]  
Partner 1: [Helps measure.]

**Tasks 5-10**

Ryan: You ready?  
Ryan: [Drops ball down ramp.]  
Partner 1: [Writes down data.]  
Ryan: [Drops ball down ramp.]  
Partner 1: We could have easily modified your procedure.  
HT April: You can specify where on the table you want to put the ramp, and you can specify where you want the [inaudible] to go.  
Ryan: [Drops ball down ramp.]  
Partner 1: Two more times.  
Partner 1: Why don’t we just put it right here?  
Partner 1: Sorry, I forgot to reset it.  
Ryan: [Drops ball down ramp.]  
Partner 1: [Inaudible] how far that is.  
Partner 1: All right, so let’s go measure the height.  
Ryan: [Works with data.]  
Partner 1: [Works with data.]  
Ryan: Okay, I got an average of 8-5-0.  
Partner: Yeah, I did that last, too.  
Ryan: [Works with data.]  
Partner 1: [Works with data.]

*Investigator Commentary:* Ryan was active throughout this experiment. While he chose to involve himself primarily in actions not involving the ILAB tools, he demonstrated understanding of the ILAB motion sensor used in this lesson. He measured several distances and ran repeated tests by rolling the ball down the ramp. Lab partners 1 and 2
were also very involved in how the activities were carried out, but Ryan contributed more
time engaged in lab actions than did his partners. Toward the end of the lesson, Ryan’s
contributions were momentarily minimized by his lab partners and he worked on his
computer alone for a time, but his many contributions prior to that point were greater
overall than theirs. He was fully integrated into most aspects of the experiment.
Lesson 4 Analysis: Falling Mass Cars (I-Video)

Table 7-5: Lesson 4 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:10.0 - 1:31.4</td>
<td>Working on computer</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>2:09.3 - 2:16.3</td>
<td>Adjusting the setup</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>2:19.2 - 2:41.4</td>
<td>Adjusting the setup</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>2:44.7 - 2:52.3</td>
<td>Working on computer</td>
<td>I</td>
<td>4</td>
</tr>
<tr>
<td>3:01.0 - 4:10.0</td>
<td>Working on computer</td>
<td>I</td>
<td>5</td>
</tr>
<tr>
<td>8:06.2 - 8:15.2</td>
<td>Changing the setup</td>
<td>N</td>
<td>6</td>
</tr>
<tr>
<td>8:53.3 - 8:59.7</td>
<td>Running test</td>
<td>N</td>
<td>7</td>
</tr>
<tr>
<td>10:24.0 - 10:28.3</td>
<td>Running test</td>
<td>N</td>
<td>8</td>
</tr>
<tr>
<td>10:30.4 - 10:37.7</td>
<td>Setting up test again</td>
<td>N</td>
<td>9</td>
</tr>
<tr>
<td>11:10.2 - 11:15.7</td>
<td>Running test</td>
<td>N</td>
<td>10</td>
</tr>
<tr>
<td>13:52.6 - 13:55.4</td>
<td>Running test</td>
<td>N</td>
<td>11</td>
</tr>
<tr>
<td>14:15.7 - 14:19.6</td>
<td>Running test</td>
<td>N</td>
<td>12</td>
</tr>
<tr>
<td>15:46.3 - 15:50.9</td>
<td>Running test</td>
<td>N</td>
<td>13</td>
</tr>
<tr>
<td>16:11.2 - 16:14.2</td>
<td>Running test</td>
<td>N</td>
<td>14</td>
</tr>
<tr>
<td>17:25.3 - 17:29.4</td>
<td>Running test</td>
<td>N</td>
<td>15</td>
</tr>
<tr>
<td>17:56.3 - 18:00.1</td>
<td>Running test</td>
<td>N</td>
<td>16</td>
</tr>
<tr>
<td>18:27.0 - 22:11.2</td>
<td>Cleaning up</td>
<td>N</td>
<td>17</td>
</tr>
<tr>
<td>18:54.5 - 19:17.6</td>
<td>Cutting string off car</td>
<td>N</td>
<td>18</td>
</tr>
</tbody>
</table>

Tasks 1-5

Partner 1: So what did you get?
Ryan: Um, I’m not really sure. I could look at the data table, but I don’t think ...
Ryan: No, we want to take the derivative.... Oh, I guess we could do that, yeah.
Ryan: You know what, all the data should be good now for this run.
Partner 1: By looking at it I can see it’s all zero, but you might as well do it just to be consistent.
Ryan: [Working on computer.]
Ryan: The acceleration was like 0.000 something.
Partner 1: But rounding would become like zero right?
Ryan: Yes.
Partner 1: So let’s say 0.0 meters per second squared.
Partner 1: We’re going to get some small ... wait, how many, if we’re trying to say two sig figs, what is it?
Partner 1: Ok, it’s one. It’s 2.0 times 10 to the negative 4.
Ryan: Let me write that down.
Ryan: The car is in place.
Ryan: [Adjusting the setup.]
Partner 1: Okay, that’s for trial one.
Ryan: [Adjusting the setup.]
Ryan: Okay.
Ryan: [Working on computer.]
HT April: Outstanding, it didn’t move.
HT April: Are we doing a control or something?
Ryan: Yeah.
April: Oh, okay, gotcha, gotcha.
Ryan: [Working on computer.]

Task 6

Partner 1: Okay, so you have data?
Ryan: Why don’t I let you come over here and drive the computer?
Partner 1: You sure you have data?
Ryan: I’m not ... um, I believe so, but ... 
Partner 1: I think it was too fast. We gotta use less mass because it shows all zeros.
Ryan: Okay.
Ryan: Wanna try just the five of the hanger?
Partner 1: All right.
Ryan: [Changing the setup.]

Task 7

Partner 1: I’ll start the collecting and you release it?
Ryan: Yeah.
Partner 1: And make sure you don’t let the car drop on the floor.
Ryan: Yeah.
Partner 1: I hit spacebar to start it?
Ryan: Yeah.
Partner 1: Tell me when it’s ready.
Ryan: Ready.
Partner 1: [Hits spacebar on computer to start data collection.]
Partner 1: Your hand is on the pulley. It’s not moving.
Ryan: Oh, right.
Partner 1: All right, do that again because it stopped collecting.
Ryan: Sorry about that.
Partner 1: Tell me when it’s ready.
Ryan: Ready.
Ryan: [Running test.]
Partner 1: Okay, there’s a curve on the graph.
Ryan: For position?
Ryan: Yeah, position should be a curve.

Tasks 8-10

Partner 1: Tell me when you’re ready.
Ryan: Ready.
Partner 1: [Starting collection.]
Ryan: [Running test.]
Ryan: Oh, you know what I think happened?
Ryan: [Setting up test again.]
Partner 1: 0.046, 0.046.
Ryan: What was the other one?
Partner 1: 0.01.
Ryan: So are we done with it?
Partner 1: I think we need one more trial.
Ryan: Okay.
Partner 1: All right, this should go quickly. Ready?
Ryan: Ready.
Partner 1: [Starting collection.]
Ryan: [Running test.]

Tasks 11-12

Ryan: [Running test.]
Partner 1: So, this one seems to smooth it out after, so it might not be an issue.
Partner 1: 0.45.
Ryan: Okay, that’s not too bad.
Partner 1: Okay, ready?
Ryan: Yeah.
Partner 1: [Starting collection.]
Ryan: [Running test.]

Tasks 13-14

Ryan: [Running test.]
Partner 1: This really wasn’t spinning. I don’t think it’s working.
Ryan: Yeah.
Partner 1: Oh, I did something really stupid.
Ryan: What?
Partner 1: I moved the motion detector to get in the box and never put it back. Okay, so let’s do that again.
Ryan: Okay.
Partner 1: [Starting collection.]
Ryan: [Running test.]

Tasks 15-16

Partner 1: Um, starting collection now. Yes start, no erase, and continue, right?
Ryan: Yeah.
Ryan: [Running test.]
Ryan: Did that get any good data?
Partner 1: Yeah, it got a little stretch of good data.
Ryan: Uh, oh.
Ryan: I just wasn’t sure if my hand was in the way.
Partner 1: We had enough points to do a linear fit.
Ryan: Okay.
Partner 1: 0.29.
Ryan: Yeah.
Partner 1: Are you ready?
Ryan: Yeah, ready.
Partner 1: [Starting collection.]
Ryan: [Running test.]

Tasks 17-18

Partner 1: [Cleaning up.]
Ryan: Um, do we want to un-rig this stuff, I suppose?
Ryan: [Cleaning up.]
Partner 1: Yes.
Ryan: What are we doing with this string, are we actually untying it?
Partner 1: The masses [interrupted].
Ryan: Do you have scissors?
Partner 1: I don’t have scissors.
Ryan: So this is hypothetical.
Ryan: [Cutting string off of car.]

Investigator Commentary: Ryan was directly involved in setting up the equipment and carrying out the experiment. He again worked primarily with tools and equipment not related to ILAB; this appeared to be a preference for the other available activities and not
a lack of understanding of, or dislike for, the ILAB tools. Ryan contributed intellectually to laboratory group discussions and directed his lab partner in using an ILAB tool to collect data. At one point he caused a delay in data collection by accidentally inhibiting the release of the car on the track. He was also involved in experiment clean up. Ryan’s contributions were accepted and valued by his lab partner.
### Table 7-6: Lesson 5 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>3:31.2 - 3:35.4</td>
<td>Plugs sensor into power cord</td>
<td>I</td>
<td>1</td>
</tr>
<tr>
<td>3:42.5 - 3:48.2</td>
<td>Screws probe into the side of the table</td>
<td>I</td>
<td>2</td>
</tr>
<tr>
<td>4:48.6 - 4:59.1</td>
<td>Examines spring by touch</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>5:12.2 - 5:13.7</td>
<td>Types on computer</td>
<td>I</td>
<td>4</td>
</tr>
<tr>
<td>6:34.2 - 6:35.2</td>
<td>Picks up both springs</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>6:45.0 - 6:46.0</td>
<td>Hangs weight on spring</td>
<td>N</td>
<td>6</td>
</tr>
<tr>
<td>6:50.1 - 6:51.8</td>
<td>Brings spring to the edge of the table</td>
<td>N</td>
<td>7</td>
</tr>
<tr>
<td>7:55.2 - 8:03.6</td>
<td>Adjusts spring</td>
<td>N</td>
<td>8</td>
</tr>
<tr>
<td>8:16.3 - 8:23.0</td>
<td>Places the weight onto the spring</td>
<td>N</td>
<td>9</td>
</tr>
<tr>
<td>9:04.7 - 9:19.9</td>
<td>Places a weight onto the pendulum</td>
<td>N</td>
<td>10</td>
</tr>
<tr>
<td>9:27.9 - 9:33.9</td>
<td>Types on computer</td>
<td>I</td>
<td>11</td>
</tr>
<tr>
<td>10:56.5 - 11:25.0</td>
<td>Types on laptop</td>
<td>I</td>
<td>12</td>
</tr>
<tr>
<td>11:27.0 - 11:29.6</td>
<td>Types on laptop</td>
<td>I</td>
<td>13</td>
</tr>
<tr>
<td>11:29.6 - 11:30.9</td>
<td>Adjusts pendulum</td>
<td>N</td>
<td>14</td>
</tr>
<tr>
<td>11:34.9 - 11:38.8</td>
<td>Uses computer</td>
<td>I</td>
<td>15</td>
</tr>
<tr>
<td>18:16.0 - 18:19.9</td>
<td>Types on computer</td>
<td>N</td>
<td>16</td>
</tr>
<tr>
<td>18:26.9 - 18:27.9</td>
<td>Pulls on spring</td>
<td>N</td>
<td>17</td>
</tr>
<tr>
<td>18:33.3 - 18:34.3</td>
<td>Pulls on pendulum</td>
<td>N</td>
<td>18</td>
</tr>
<tr>
<td>24:44.9 - 24:51.8</td>
<td>Types on computer</td>
<td>I</td>
<td>19</td>
</tr>
<tr>
<td>24:51.8 - 24:57.4</td>
<td>Stretches out the spring and pendulum</td>
<td>N</td>
<td>20</td>
</tr>
<tr>
<td>24:57.4 - 25:11.9</td>
<td>Uses ILAB tool to collect data</td>
<td>I</td>
<td>21</td>
</tr>
</tbody>
</table>
Tasks 1-2

Ryan: [Plugs sensor into power cord.]
Ryan: Can you screw that down?
Partner 1: Yeah.
Partner 1: [Screws in the motion sensor probe.]
Ryan: You want me to, oh, that works, it doesn’t matter. I thought it did but it occurred that it doesn’t.
Ryan: [Screws the probe into the side of the table.]

Tasks 3-4

Partner 1: That’s a very interesting spring.
Ryan: This is sort of interesting.
Ryan: [Examines spring by touch.]
Ryan: We have been using ... I fixed that ...
Partner 1: [Reads from worksheet.]
Partner 1: Uh, you still didn’t fix it to my normal ...
Ryan: We’ve been using ...
Ryan: [Types on computer.]

Tasks 5-7

Ryan: So we need, oh, we are testing both of these springs, okay.
Ryan: [Picks up both springs.]
Partner 1: Here’s a piece of tape before you stick that on.
Ryan: I think we can just hang it on this.
Partner 1: Okay.
Ryan: [Hangs weight on spring.]
Ryan: This is a big spring.
Partner 1: Does it come by the floor?
Ryan: [Brings the spring to the edge of the table.]
Ryan: I don’t know, but I suspect that it might just do it.

Tasks 8-9

Ryan: [Adjusts the spring.]
Partner 1: [Returns with meter stick.]
Partner 1: Or I could go get a shorter spring.
Ryan: Now you say you can get a shorter spring.
Partner 1: Let’s use the shorter spring first, then.
Ryan: Okay, can I do it?
Partner 1: [Hands spring to Ryan.]
Ryan: Can I get it on? Probably.
Ryan: [Places the weight onto the spring.]
**Tasks 10-11**

Ryan: [Places a weight onto the pendulum.]
Ryan: Do you think it will make a difference?
Partner 1: We’ll find out.
Partner 1: [Measures spring with the meter stick.]
Ryan: [Types on computer.]

**Tasks 12-15**

Ryan: You getting ready to oscillate it in a second?
Partner 1: I have it started, I have it started.
Ryan: Okay.
Ryan: [Types on laptop.]
Partner 1: Is it analyzing it?
Ryan: [Types on laptop.]
Ryan: [Adjusts pendulum.]
Partner 1: It’s still balancing ...
Ryan: [Uses computer.]

**Tasks 16-18**

Ryan: I’m telling you the force should always be the same.
Partner 1: [Measures spring with meter stick.]
Ryan: Yeah.
Partner 1: But the springs are the same lengths.
Ryan: Okay, well, it’s 3.6.
Ryan: [Types on computer.]
Partner 1: [Writes on worksheet.]
Ryan: Could you insert that?
Partner 1: What?
Ryan: [Pulls on spring.]
Ryan: You have to insert that, to start it.
Partner 1: Oh, we don’t need it.
Ryan: [Pulls on pendulum.]

**Tasks 19-21**

Partner 1: Okay, so, so right now it’s oscillating.
Ryan: Okay, um [inaudible].
Ryan: [Types on computer.]
Ryan: [Stretches out the spring and pendulum.]
Ryan: [Uses ILAB tool to collect data.]
Investigator Commentary: Ryan involved himself in much of the laboratory setup. He investigated through touch many of the objects used in this experiment including the springs and pendulums. He used the Vernier motion sensor and JAWS to measure the acceleration of the pendulum. Ryan’s discussions with his lab partner demonstrated full incorporation into his lab group. HT April had very little interaction with Ryan. His physical manipulations of the wires and springs illustrated his excellent comprehension of what was to be done as well as his motor skills. He also demonstrated special skill in knowing where objects were and how they interacted with one another.
**Graphic Analysis of Video Data**

The data illustrated in Figures 7-1 and 7-2 show the percent of time engaged (PTE) for the BLV student and his sighted lab group partners in performing laboratory-goal-directed actions during laboratory lessons, as described in Chapter 4. For lessons involving more than one sighted partner, the separate PTEs for the partners were combined. To help in understanding the graphical data, instances of multiple partners are noted in the text describing the PTE results for the individual lessons. Sighted students may have rotated from lab to lab. Ryan is indicated in blue, and the sighted partners are indicated in red. Figure 7-1 shows the results of the two lessons conducted without the use of ILAB tools, and Figure 7-2 shows the results of the three lessons conducted with ILAB tools.

In Lesson 1, Ryan exhibited 70.8% PTE while his partner exhibited 29.2% PTE. In Lesson 2, Ryan’s observed PTE was 62.8%, and the sighted student’s was 37.2%. Ryan was also substantially involved in all three ILAB-tools lessons at 77.3%, 67.3%, and 69.0% PTE in Lessons 3-5, respectively. For Lesson 3, he had two partners, which makes his 77.3% PTE even more remarkable, since the two partners together contributed only 22.7%. He consistently participated in lab activities on an equal or greater basis than did his sighted counterparts and was fully involved in all lessons. The presence or non-presence of ILAB tools seemed to have little impact on Ryan’s PTE results, although his overall performance was somewhat higher during the lessons incorporating ILAB tools as compared to the lessons not incorporating ILAB tools.
Figure 7-1: Percent of Time Engaged During N-Video Lab Sessions for BLV Student and Sighted Partner

Figure 7-2: Percent of Time Engaged During I-Video Lab Sessions for BLV Student and Sighted Partner
**Video Analysis Rubric Results**

Table 7-7 shows the results of the ILAB video analysis rubric, which was designed to collect information regarding the levels of acceptance of the BLV students into their lab groups. (See the explanation in Chapter 4 and the rubric questionnaire in Table 4-5.) The three raters made numerical rankings of each of the eight rubric items for each of the five videos of Ryan included in this study. The lessons conducted without ILAB tools are labeled as “N,” while the lessons conducted with ILAB tools are labeled as “I.” The three raters are identified as “EE” for the external evaluator, “IR” for the independent rater, and “IS” for the investigator in this study. For the yes/no items (A, B, E), “yes” is coded as 1 and “no” is coded as 0. For the Likert-scale items (C1-C4 and D), “strongly agree” is 5, “no opinion” is 3, and “strongly disagree” is 1.

### Table 7-7: Video Analysis Rubric Results

<table>
<thead>
<tr>
<th>Rubric Item</th>
<th>Lesson 1 (N)</th>
<th>Lesson 2 (N)</th>
<th>Lesson 3 (I)</th>
<th>Lesson 4 (I)</th>
<th>Lesson 5 (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EE</td>
<td>IR</td>
<td>IS</td>
<td>EE</td>
<td>IR</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>C1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>C2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>C3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>C4</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 7-8 summarizes the patterns seen in Table 7-7, indicating the total number of occurrences found for each of the numerical rubric rankings and the averaged N vs. I scores for each rubric item. For the binary (yes/no) items, high inter-rater agreement was observed, whereas greater variability was seen in the Likert-scale ratings. This is consistent with the inter-rater reliability coefficients discussed in detail in Chapter 10.

Table 7-8: Patterns Observed with the Video Analysis Rubric

<table>
<thead>
<tr>
<th>Rubric Item</th>
<th>Summary of Scores</th>
<th>Average N</th>
<th>Average I</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14 ones of 15 possible</td>
<td>1.0</td>
<td>0.89</td>
</tr>
<tr>
<td>B</td>
<td>13 ones of 15 possible</td>
<td>1.0</td>
<td>0.78</td>
</tr>
<tr>
<td>C1</td>
<td>6 fives, 7 fours, 1 three, 1 two</td>
<td>4.3</td>
<td>4.1</td>
</tr>
<tr>
<td>C2</td>
<td>10 fours, 3 threes, 2 twos</td>
<td>3.5</td>
<td>3.6</td>
</tr>
<tr>
<td>C3</td>
<td>5 threes, 10 twos</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>C4</td>
<td>1 five, 1 four, 3 threes, 8 twos, 2 ones</td>
<td>2.2</td>
<td>2.6</td>
</tr>
<tr>
<td>D</td>
<td>3 fives, 10 fours, 1 two, 1 one</td>
<td>4.3</td>
<td>3.6</td>
</tr>
<tr>
<td>E</td>
<td>13 ones of 15 possible</td>
<td>1.0</td>
<td>0.78</td>
</tr>
</tbody>
</table>

For items A, B, and E, except for Lesson 3, the raters generally agreed that the BLV student was significantly involved in discussions related to the completion of the laboratory goal, that the sighted students accepted the contributions of the BLV student, and that the BLV student was included in the collaborative participation of the group, respectively. All zeroes in A, B, and E happened in Lesson 3. This is a somewhat different story than that seen in the Video Task Analysis section and the Graphic Analysis of Video Data section. With the rubric, solely the investigator in this study rendered a zero for item A, but both the external evaluator and the investigator put zeroes for items B and E, so Ryan must have been more minimized for these two items in Lesson 3 than was evident with the video task analysis and graphic analysis of video data.
He did work on his computer alone for awhile during this lesson, which may help account
for these zeroes. The averaged rankings for the raters for items A, B, and E were
somewhat lower for the I-lessons than for the N-lessons, indicating a mild to moderate
decline in each of these items.

In C1, the averaged rankings for the raters indicate that the BLV student
expressed high interest in the science experiments but with a slight decrease during the
ILAB lessons. Again there was substantial rater disagreement in Lesson 3 and also in
Lesson 4, with differences in ratings of two levels for each of those two lessons. For item
C2, the raters generally agreed that the level of interest of the BLV student stayed the
same throughout the lessons, although Lesson 3 was again problematic with disagreement
of two levels, as also was Lesson 2. In C3, the level of interest of the BLV student did not
increase over the course of the experiments, neither for the averaged N scores nor the
averaged I scores. In the case of item C4, the averaged ratings show that the level of
interest of the BLV student generally did not decrease as the lessons progressed.
However, Lessons 1 and 2 each showed two levels of disagreement among raters, while
Lesson 3 exhibited three levels of disagreement.

For item D, the raters generally agreed that the techniques used by the BLV
student were perceived by the sighted members of the lab group as beneficial. This
agreement was quite strong except for Lesson 3, which exhibited three levels of
disagreement among raters, including some very low scores which brought down the
averaged I score.

Apparently, Ryan had some problems in Lesson 3 that were not made evident in
either the video task analysis or the graphic analysis. Inadequacies in the rubric that could
have led to confusion among the raters may also have contributed to the wide variations in scores for Lesson 3, but this does not fully explain why Lesson 3 exhibited more disagreement than did the other lessons.

None of the lessons had complete agreement across all rubric items. Rater disagreements of only one level within individual Likert-scale rubric items may have been due to small variations in interpretation and/or perception, whereas disagreements of greater than one level may have been at least partially caused by unintentionally ambiguous terminology in the rubric itself, as discussed in Chapter 10.

**Summary**

Ryan, with his advanced lab skills, was able to contribute significantly to the laboratory lessons both with and without ILAB tools, as illustrated in the Video Task Analysis section and Graphic Analysis of Video Data section. In fact, his percent of time engaged in goal-directed actions during laboratory lessons was greater than that of his partners for all five lessons analyzed. He developed the philosophy of trying to help his partners as much as he was able, favorably impacting his willingness to participate in lab activities. His video analysis rubric scores were quite good but may have been negatively affected by ambiguities in the wording of the rubric items, and he may have had some difficulties in Lesson 3 that were not apparent with the other modes of analysis.

Ryan was very involved in the labs both with and without ILAB tools, which may have been partially due to his having used ILAB tools in two previous chemistry classes, as well as having learned the value of being organized and possessing good lab skills. Even though he was dependent on touch and hearing to conduct all laboratory actions and
observations, he was not afraid to get his hands dirty or of getting injured, whether or not he had ILAB tools available. His good set of lab skills combined with his personal philosophy of helping out whenever possible may have contributed to the observed low impact of the ILAB tools.

His ability to work with his lab partners also directly impacted his ability to participate. He seemed to be well respected by his partners, as seen in the Video Task Analysis section and Video Analysis Rubric section, and noted in HT April’s post-school-year interview. He thrived in the guided-inquiry atmosphere and enjoyed problem solving as a member of a group. As also mentioned by HT April in her interview, at the beginning of the school year Ryan was relatively quiet and hesitant to speak up during lab discussions, but became more outgoing and willing to contribute his ideas as the school year went on. This was a significant change in his behavior and revealed a shift in his mindset about how he could involve himself in lab activities. This shift in mindset may have contributed to the 11-point increase in his SAI II scores from pre-school-year to post-school-year.

Ryan felt very comfortable with the ILAB tool functionality, as was demonstrated in all videos of ILAB-tools lessons. He also had a strong comprehension of computer assistive technology in both the ILAB-tools lessons and non-ILAB-tools lessons. This aided him in his ability to conduct data analysis. Additionally, Ryan took laboratory preparation seriously and possessed a high intellect, both of which gave him a strong problem-solving ability. His teachers commonly referred to him as a genius. He was able to comprehend concepts quickly and explain his arguments to his lab partners; many times he was able to persuade them to see his points of view.
Chapter 8

Rollinsville High School Case Study

Rollinsville High School (a pseudonym) is a magnet institution located in a large metropolitan city on the East Coast of the United States. As a magnet, the school enrolls students from a wide geographical area and multiple school districts. Rollinsville’s mission is to equip students with the knowledge, skills, and attitudes to become productive citizens who foster change within the global community. Students are required to apply for admission on an annual basis to maintain their enrollment or, alternatively, return to their local schools.

Demographics of School

The Rollinsville student population was approximately 2,000 in grades nine through twelve, with 51% male and 49% female. The school had a faculty of 145 including 11 science teachers. Reported student racial breakdown was African-American 63%, white 33%, Asian 2%, and Hispanic 2%. Eligibility for reduced-price or free lunch was 26%. For the advanced placement (AP) chemistry class that was involved in this study, there were four African-American students, four Asians, and 10 Caucasians. Ten were male and eight were female.

Background of Student

The student at Rollinsville was named Neil (a pseudonym). He was enrolled in a senior-level AP chemistry class. He was 18 years of age at the time of this study and had
been accepted into a major four-year university in a mid-Atlantic state. He was planning to pursue a degree in math education. He lived in a single-parent household and was the primary caregiver at home as a result of medical issues relating to the parent.

Neil was able to read large print; thus, his lab procedure instructions were provided in large-print hard copies. He also used screen magnification software to aid his viewing of information on computer screens. Additionally, he could see some colors if they were held close to his face. He had some apprehension toward laboratory activities but was excited about his use of the ILAB tools in AP chemistry class. Neil had previously used ILAB tools in regular chemistry class during his junior year at Rollinsville. He tended to work well in lab groups but typically had been given the task of data recorder prior to his exposure to ILAB. He indicated he would use the ILAB items when either he or the teacher felt they would be helpful, although he believed the teacher was nervous about the ILAB tools. Neil also indicated some frustration with his teacher as a result of a textbook not being available to him in Braille. Neil was responsible for setting up his workspace for lab sessions to ensure he was familiar with the location of all tools, supplies, and equipment. He said he felt that the best part of the AP chemistry class was the labs and his ability to participate in them as a result of the ILAB tools.

**Background of Teacher**

RT Nancy was the pseudonym of the AP chemistry teacher (Rollinsville teacher Nancy). She had a master’s degree in science education. As the AP chemistry course progressed, negativity between the teacher and the class increased. As a result, RT Nancy
lost her excitement for teaching to the point that she decided to leave the profession and pursue another career path. However, she was committed to offering Neil the best chemistry learning experience that she could provide for him.

The AP class was a one-semester course. Her classroom was a typical chemistry lab with benches, hoods, and other standard laboratory equipment for students to use. Her classes accommodated 28 students on average. RT Nancy chose the partners for the lab groups in her class. Lab groups varied in size from two to four students, based on the amount of lab equipment available. RT Nancy gave Neil the opportunity to work with the ILAB tools during the period just before class. RT Nancy had taught Neil and another BLV student in her regular chemistry class during the academic year prior to the AP chemistry class.

### Classroom Resources

The laboratory classroom was equipped with lab benches and sinks at every station, as well as two hoods for experimental work and desks for the students to use during lecture. Each lab bench had the necessary power outlets to allow for the use of stir plates and other electronic lab equipment. The classroom also had all of the required safety equipment, and the school provided all necessary waste disposal. Class periods were 85-90 minutes in length.

The investigator provided RT Nancy with all needed Vernier Software & Technology probe ware and software. JAWS was already installed on Neil’s laptop computer. The investigator loaded Logger Pro and the necessary JAWS scripts onto Neil’s laptop. The classroom was shared with other teachers for other classes. It was
because of this sharing of space that some of the ILAB tools were stolen. In particular, analytical balances were stolen twice from this one classroom. RT Nancy had access to a storage room next to the classroom where she could stow equipment and began keeping the ILAB tools under lock and key in fear of theft.

**Relationship between Investigator, Teacher, BLV Student, and Parents**

The investigator worked directly with RT Nancy on ILAB tool training prior to the first AP chemistry class meeting. The teacher came to Penn State University for this training. Other communications occurred via telephone and email. RT Nancy was highly motivated to learn how to provide a positive laboratory educational experience for Neil. Her having served as Neil’s chemistry teacher during the previous school year enhanced her ability to adapt chemistry lab activities with minimal intervention by the investigator. She expressed a strong commitment to Neil’s learning. This commitment helped facilitate Neil’s hands-on learning experience. Additionally, RT Nancy participated in ILAB team conference calls every 60 days, giving her the opportunity to share her experiences as well as learn from other teachers participating in the ILAB study.

Once the school year began, very little telephone and email communication took place between the investigator and Neil, and none between the investigator and Neil’s parent. This was similar to what had occurred during Neil’s previous chemistry class. Most concerns were brought to the investigator’s attention by RT Nancy.
Interview Data

The following are excerpts and/or summaries of dialogue between the investigator and the BLV student, and between the investigator and the teacher. The questions asked were based on the standard interview scripts for the ILAB study (Tables 4-1, 4-2, 4-3); follow-up questions for clarification were also asked, dependent on the student’s or teacher’s responses to the initial queries. These particular questions were chosen for analysis because of their significance to the incorporation of the BLV student into lab groups, his efficacy with the ILAB tools, and his interest in science. Commentary from the investigator follows the excerpts/summaries for each interview.

Excerpts, Summaries, Commentary: Pre-School-Year Student Interview

No pre-year interview was conducted for Neil because he had participated in the ILAB study during a previous chemistry class earlier that calendar year, and a visit to Rollinsville at the beginning of the AP chemistry class was not scheduled due to travel budget restrictions.

Excerpts, Summaries, Commentary: Post-School-Year Student Interview

So what has been your favorite part of chemistry class?

“The labs. I might have not said that in years past, but they probably were the only good part of that [class].”
What made it so good?

“I guess just to get to work with other people and to discuss what we were doing; whereas every other day it would be [our teacher] just reading out or giving notes, and us just sitting there by ourselves, not working together.”

Did you like the laboratory portion of the class?

“Yes.... I liked that I actually got to do something in most of the lab, whereas before I would do basically nothing.”

Do you think your visual impairment made working in the lab more difficult?

“Yes.”

When you’re working as part of a lab team, do you tend to work on the things that are more comfortable for you?

“Usually. It depended on the lab.”

Do you think this class helped you to realize that you could do science and that it wouldn’t be too hard for you even if you didn’t necessarily like the class material?

“Yes, I guess so.”

Investigator Commentary: Neil indicated this lab experience was more positive than previous ones because, unlike in previous labs, he had been allowed to participate in some hands-on activities. However, he often participated only in the aspects of these chemistry labs with which he felt comfortable. He did not indicate a willingness to go too far outside his comfort zone. Still, the lab sessions were the most enjoyable part for Neil of the AP chemistry course. He felt he had been able to contribute to the completion of
lab goals when he had ILAB tools available. When he did not have the tools available, he felt he contributed little, if any, to completion of lab group goals.

**Excerpts, Summaries, Commentary: Post-School-Year Teacher Interview**

*Did Neil primarily work with the same group members, or did you rotate the participants?*

“I rotated the participants a little bit until we really found a group that worked well with him. Originally I had him with what seemed like more outgoing students because they were showing off in class. When they worked with Neil, they didn’t explain anything and they didn’t try to be descriptive or anything so I switched him to a group where it had one kid who was just going super fast through all of the labs, and that slowed that one kid down because he was so descriptive and helped Neil out a lot.”

*Within the groups, did the student remain in his comfort zone?*

“He stepped in and out of his comfort zone. But he worked with his partners diligently and there were times that he’s very cautious in what is in each container because he doesn’t want to get into corrosive stuff, so the first lab was probably the worst for him because there was concentrated sulfuric acid. Any time he was doing, any time that there was a concentrated chemical, he was worried about it.”

*Did you notice any increase or decrease in his self-efficacy with the tools as the school year went on?*

RT Nancy indicated Neil’s efficacy with the tools increased slightly over the duration of the course. Neil also became more proactive in the classroom as time went on.
You found Neil to pull his share of the weight?

“The things he wouldn’t pull his share of the weight in is mostly that the classroom was very cluttered and there wasn’t much space to move around. He wouldn’t get chemicals, but he would help with the cleanup as much as he could. He wasn’t usually the one running to the trash can, which I couldn’t ever get the custodians to put back in the same spot.”

How well did Neil work with the other students?

“I think when he first started out, the lab partners that he had before [partner name], he was a little bit intimidated by and didn’t work well with them. But I think he worked fairly well with [partner name] and he got better at working with his lab partners as he moved along, just kind of advocating for himself and having them value his opinion on how to do things.”

How would you say Neil’s visual impairment impacted his participation in the lab?

“He was kind of frightened of pouring stuff and making sure that he wasn’t spilling. But other than just his over-cautiousness on some things, the impact in the lab as a whole, in all of the labs we did, there was very little. Of course when it came to telling colors, colors were some of the hardest things in the qualitative analysis to do. It was easier for him to do if it was cloudy or if it changed colors, what color it changed to.”

Investigator Commentary: RT Nancy indicated Neil had worked with several lab partners but had not been very compatible with the initial pairings. Once she found a partner who described what was going on during the lab, she kept that student as Neil’s partner for the rest of the course. She observed Neil’s increased self-efficacy with the tools as the class
went on, resulting as Neil became more familiar with the tools and software. He used his residual vision as much as possible to identify precipitates and colors of solutions. He used JAWS to complement his viewing of the computer screen. His physical mobility was limited in the classroom because of clutter, which forced his group partners to obtain the chemicals. Overall, his comfort with participating in the labs increased as the school term progressed, as did his comfort level regarding ILAB tool functionality.

**SAI II Survey Data Pre/Post School Year**

Neil’s SAI II survey data appear in Table 8-1. The table indicates the six attitudinal constructs, as discussed in Chapter 4. The Likert score totals for each construct are from the 40 questions in the SAI II instrument (see Table 4-4 in Chapter 4), with positive questions categorized as “A” and negative questions categorized as “B.” The “B” questions were reverse-coded for point values, meaning that higher scores indicate better attitudes both for the “A” and “B” questions, as described in Chapter 4. At the bottom of the table are total shifts in attitude for all “A” items and all “B” items, and a total for “A” and “B” together.

Neil exhibited a substantial improvement in attitude toward science from the pre-school-year survey to the post-school-year survey, as illustrated by his increase in “all AB” score of 15 points. His initial attitude toward science was almost completely neutral/undecided, with a pre-year “all AB” score of 124, so participating in the ILAB study brought him higher into the positive range. The greatest impact was for constructs #6 and #4, with increases of 8 points and 6 points, respectively. A 2-point increase was
seen in construct #5. No change was seen for constructs #1 and #3, and construct #2 had a 1-point decline.

An interesting observation to note, however, is that all of Neil’s declines were in the “B” items: 1-B, 2-B, 3-B, and 5-B. What this means is unclear, but this trend does not appear in the data of the other participants. It is clear that Neil generally scored the “A” and the “B” items higher on the post-year test than on the pre-year test, but these higher scores for the “B” items actually revealed declines once they were reversed-coded for analysis. The fact that the ambiguous wording of some of the “B” items could have obscured their intended negativity – and thus could have been perceived as positive – may have contributed to this.
Table 8-1: SAI II Data for Neil, Pre/Post School Year 2007-08

<table>
<thead>
<tr>
<th>Attitudinal Construct</th>
<th>Pre-Year</th>
<th>Post-Year</th>
<th>Difference Pre/Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-A</td>
<td>12</td>
<td>14</td>
<td>+2</td>
</tr>
<tr>
<td>1-B</td>
<td>11</td>
<td>9</td>
<td>-2</td>
</tr>
<tr>
<td>2-A</td>
<td>13</td>
<td>15</td>
<td>+2</td>
</tr>
<tr>
<td>2-B</td>
<td>9</td>
<td>6</td>
<td>-3</td>
</tr>
<tr>
<td>3-A</td>
<td>12</td>
<td>13</td>
<td>+1</td>
</tr>
<tr>
<td>3-B</td>
<td>14</td>
<td>13</td>
<td>-1</td>
</tr>
<tr>
<td>4-A</td>
<td>9</td>
<td>15</td>
<td>+6</td>
</tr>
<tr>
<td>4-B</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>5-A</td>
<td>9</td>
<td>13</td>
<td>+4</td>
</tr>
<tr>
<td>5-B</td>
<td>10</td>
<td>8</td>
<td>-2</td>
</tr>
<tr>
<td>6-A</td>
<td>8</td>
<td>16</td>
<td>+8</td>
</tr>
<tr>
<td>6-B</td>
<td>14</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>All A</td>
<td>63</td>
<td>86</td>
<td>+23</td>
</tr>
<tr>
<td>All B</td>
<td>61</td>
<td>53</td>
<td>-8</td>
</tr>
<tr>
<td>All AB</td>
<td>124</td>
<td>139</td>
<td>+15</td>
</tr>
</tbody>
</table>
Overview of the Five Laboratory Lessons

This section contains synopses of what occurred in each of the five audio-video-recorded laboratory lessons. The lessons were part of the school’s regular curriculum. The following descriptions were written from the lesson transcripts. The synopses are not intended as complete representations of activities during each lesson, but rather are intended to provide readers with an idea of what the BLV student experienced. Short descriptions regarding how the BLV student interacted with his group partners are also included. Lab groups varied in size from lesson to lesson, comprising two or more people. Only the lab partners with whom Neil had the most communications and interactions are noted in the following synopses.

Please note that while the lessons not incorporating the ILAB tools are listed first, it was not by design that these lessons chronologically preceded those with ILAB tools. However, it is by design that the two N-lessons are chronological in relationship to each other, as are the three I-lessons. The I-lessons are listed in the order in which they actually occurred to better illustrate the BLV student’s progress, if any.

Lesson 1 Synopsis: Alum Analysis (N-Video)

RT Nancy began by explaining to Neil that potassium hydroxide was dangerous to the touch, and hands must be washed immediately if they came into contact with it. Neil’s partners began to measure out the solid potassium to place into water to create potassium hydroxide. They used a beaker and later switched to a flask. A classmate gave Neil and his partners the sulfuric acid to add to the potassium hydroxide solution. RT Nancy stated to Neil’s group that they should measure the amount they needed by means
of a graduated cylinder, not a beaker. Neil’s partners realized they had 100 mL sulfuric acid and they needed 125 mL, so they began to search for a 125 mL flask. RT Nancy said there were only two 125 mL flasks, and that they had to wash out their flask with a lot of water and a little sulfuric acid to neutralize any potassium hydroxide left over in the flask. One partner began preparing a soda can to be cut up into aluminum pieces. Another partner cut the aluminum and weighed it. Neil and his partners moved to the hood to put the aluminum and potassium hydroxide together to heat on a hot plate. They observed the solution turning black. Next, Neil and his partners used a small wad of glass wool and a funnel attached to a ring stand to pour the solution into a beaker. RT Nancy suggested to the group to use water to assure that all the “sludge” from the potassium hydroxide and aluminum solution was out of the beaker. Lastly, Neil and his partners washed the glassware in the sink.

Lesson 2 Synopsis: Heat of Magnesium (N-Video)

In this exercise, Neil and his partners were to read the change in temperature of a reaction. Neil used the thermometer while his partners discussed the initial and final temperatures of the solution with another classmate. One partner asked Neil to stir the solution some more because there appeared to be “stuff at the bottom” and reread the thermometer. A partner recorded and calculated the data. RT Nancy told Neil’s group to pour that solution down the drain and asked if they had finished both parts of the experiment. One partner replied that they had only done the first part. RT Nancy then explained to the group that they needed to make sure to measure the starting temperature of the hydrochloric acid before adding the magnesium sulfate because the temperature
could change. Neil and his group members discussed the amount of hydrochloric acid needed but were confused which unit should be used to measure the acid. RT Nancy explained that hydrochloric acid was measured in liters and that they needed to record in their lab notebooks exactly what was being weighed as it appeared on the scale. Neil held the thermometer in the solution while a partner read the temperature at 23° Celsius. The magnesium was added and a partner read the temperature at 44° Celsius. Finally, RT Nancy said to pour the solution down the drain and that Neil could clean up his computer.

**Lesson 3 Synopsis: Colligative Properties (I-Video)**

Neil used a dropper to place the solution into a test tube. His partner warned him to not touch the inside of the test tube. Then the partner handed him a second test tube, and Neil determined the mass of the new liquid. Neil inserted a thermometer into the test tube, and he and his partner decided to wait until the temperature peaked to start collecting data. After the temperature peaked and started going down, Neil agitated the solution and started data collection on the computer. He stirred the solution with the thermometer. His partner indicated that when the temperature started to level off, it would be the final reading they would record. Neil continued to stir the solution with the thermometer and worked on the computer. Then the partner agitated the acetate while Neil continued to stir the other solution. RT Nancy told the group they needed to continue stirring to prevent crystals from forming on the temperature probe because crystals would insulate the probe from the temperature changes. Neil’s partner realized they did not have crystals forming but described their product as a “Jello-looking liquid” and asked the teacher for help. RT Nancy told them to go with a temperature that was constant for more
than one second and use that as their freezing point. She said the liquid was solidifying, which was why it looked gooey. RT Nancy explained they must wash the test tube with acetone or heat it back up. Neil heated the solution and asked his partner to look at the data table. The partner read various data values to Neil. For clean up, RT Nancy explained where the isopropanol was and said to use it to rinse the test tubes and thermometers; the ice was allowed to go down the drain.

**Lesson 4 Synopsis: Equilibrium (I-Video)**

The teacher instructed the class not to get the silver nitrate until needed because of the limited amount of the chemical available. Neil’s partner prepared and labeled the sodium cyanide, sodium nitrate, and cobalt nitrate solutions. The teacher showed Neil how to use the SALS. The partner cautioned Neil not to bump the hydrochloric acid beaker. The teacher told Neil that there would be four color changes, and the clarity would vary from cloudy to clear. Using the notched syringe, Neil transferred some of the hydrochloric acid to a test tube, while his partner assisted him in making accurate measurements. They compared their results with a classmate’s results. Neil’s partner described the solution as having the appearance of curdled milk with a spongy texture. The teacher recommended that Neil put the beaker on a white piece of paper to better differentiate between the colors. The partner described the next solution as being translucent. The partner guided Neil’s hand to a test tube to add a drop of hydrochloric acid. Neil dispensed the liquid from the notched syringe into the test tube. Neil’s partner noticed that a green solution was turning purple and offered to measure the liquid using the notched syringe. Neil was very involved in this experiment, adding chemicals to the
test tubes with his partner’s direction. Neil and his partner were involved in many tasks and exchanged communications with one another. However, the color observations were done more often by Neil’s partner than by Neil.

Lesson 5 Synopsis: Titration (1-Video)

The titration was done using a buret. Neil controlled the flow of the liquid but let out too much until he managed to control the flow to a drip. Neil’s partner poured 100 mL vinegar into an Erlenmeyer flask and told Neil to pour the 50 mL sodium hydroxide into the buret. The partner said the initial reading needed to be taken and that readings should be estimated to the nearest 0.01. Neil weighed the flask on the scale while working on a computer. His partner commented that the directions weren’t very clear. Neil recommended using the pH probe to his partner, although they’d had problems using the probe initially. The investigator fixed the problems. RT Nancy assisted Neil and his partner with the titration setup as the pH probe was placed into the vinegar solution. The partner replaced the Erlenmeyer flask with a beaker for convenience. When Neil was ready to collect data with the pH probe, the program failed to work so the investigator assisted them with the LoggerPro software. Restarting the computer helped. Neil’s partner watched the computer screen while the titration was running.

The first trial went over the neutral pH point, and they had to restart the experiment. During the second trial, Neil’s partner noticed that they had messed up the procedure, and they had to repeat the trial. Next they added 10 mL water to the vinegar. Neil reminded his partner to slow down when they got near their end point. They proceeded with caution and successfully titrated the vinegar. The mass of the beaker was
measured before and after the titration. Neil worked on his computer to record the data. They tried to make the next trial even more accurate. Because their trials had 2 mL difference, they had to make a fourth trial to titrate it within 0.5 mL.

**Video Task Analysis for Each Lesson**

The following five tables (8-2 through 8-6) were constructed to classify the types of tasks performed by Neil within each lesson. Excerpts from the transcripts of the corresponding lab group actions and dialogue are included following each table. The time stamp for each task, a description of the task performed, whether or not the task involved ILAB tools, and the task number (assigned consecutively for each chronological, discrete task that appears in each table, indicated so as to relate individual tasks in the tables to the appropriate transcript excerpts) are shown. (Note: Sometimes working on the computer is categorized as an ILAB-tool task and sometimes as a non-ILAB-tool task; the selection of “I” or “N” was based on whether the computer was being used along with an ILAB tool to take a data point or simply to take notes or perform calculations.) As stated in Chapter 4, not all actions in the video task analysis were necessarily directed toward laboratory goals.

The selected tasks are not inclusive but were chosen as illustrative to provide an overview of the types of tasks and dialogue that occurred within each lesson. Lab groups varied in size from lesson to lesson, comprising two or more people. Only the lab partners with whom Neil had the most communications and interactions are noted in the following tables and excerpts.
Lesson 1 Analysis: Alum Analysis (N-Video)

Table 8-2: Lesson 1 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:44.4 - 11:38.3</td>
<td>Stirring solution</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>16:48.3 - 17:17.6</td>
<td>Washing hands</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>33:39.9 - 33:58.4</td>
<td>Setting up hot plate</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>36:59.3 - 39:46.5</td>
<td>Washing glassware in sink</td>
<td>N</td>
<td>4</td>
</tr>
</tbody>
</table>

Task 1

Partner 1: Is that enough?
Partner 1: Should we stir it or something?
Partner 2: Stir it some.
Partner 1: Okay, good.
Partner 2: Stir it, stir it, stir it.
Neil: [Stirring solution.]
Partner 2: Oh, it got hot.
Partner 2: Just put it, that in there.

Task 2

Neil: I’m going to have to apologize cause I did not have that lab to read before this whole thing, but are we heating the KOH?
RT Nancy: We’re heating the KOH and the aluminum, and then you’re going to neutralize your KOH with sulfuric acid.
Neil: Okay, thanks.
Partner 1: All we did was measure 100 and then measure 25, right, that’s it?
Partner 1: So where do you want me to pour this in?
Neil: [Washing hands.]
Partner 2: Anybody know where the beakers are at?

Task 3

Partner 2: How do you turn this on?
Neil: You plug it in. She said once you plug it in, it turns on.
Partner 2: Okay.
RT Nancy: You may want to move that to the center so we’re not tempted to pour it on the side desk.
Partner 2: This?
RT Nancy: No, the hot plate.
Partner 2: Oh, okay, I understand.
RT Nancy: Just so you have more room.
Neil: [Setting up hot plate.]
Neil: Okay.

Task 4

Partner 2: This is water. Just wash these out, but don’t stick your hand in there.
Neil: Okay. Without sticking my hand in there.
Partner 2: Don’t touch the bottom.
Neil: [Washing glassware in sink.]
Neil: Okay.
Partner 2: Okay, if you need me, I’ll be over here.

Investigator Commentary: Neil was directed by his lab partners as to when to perform various tasks but they didn’t really ask much of him. Neil offered little intellectual verbal contribution to discussions among his lab partners. He had at most only a peripheral level of participation in this lesson. The sighted lab partners performed most of the decision-making regarding how this experiment was carried out and what the observations were.
Lesson 2 Analysis: Heat of Magnesium (N-Video)

Table 8-3: Lesson 2 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:14.8 - 2:37.1</td>
<td>Holding thermometer in solution</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>1:46.4 - 2:11.5</td>
<td>Stirring</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>2:37.1 - 2:47.9</td>
<td>Removes thermometer and places it in empty beaker</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>3:20.3 - 3:24.4</td>
<td>Places thermometer back in solution</td>
<td>N</td>
<td>4</td>
</tr>
<tr>
<td>3:24.4 - 5:06.9</td>
<td>Holding thermometer in solution</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>5:06.9 - 5:13.5</td>
<td>Transfers thermometer from beaker with solution to empty beaker</td>
<td>N</td>
<td>6</td>
</tr>
<tr>
<td>9:47.8 - 11:26.3</td>
<td>Holding thermometer in solution</td>
<td>N</td>
<td>7</td>
</tr>
<tr>
<td>11:26.3 - 11:30.1</td>
<td>Transfers thermometer from beaker with solution to empty beaker</td>
<td>N</td>
<td>8</td>
</tr>
<tr>
<td>12:06.6 - 15:36.3</td>
<td>Holding thermometer in solution</td>
<td>N</td>
<td>9</td>
</tr>
</tbody>
</table>

Tasks 1-2

Partner 1: [Stirring.]
Neil: [Holding thermometer in solution.]
Partner 2: Okay, let’s see...
Partner 1: [Reading temperature from thermometer.]
Partner 2: So we’re measuring out the change in the temperature of the reaction.
Partner 1: Yeah.
Neil: [Stirring.]
Partner 1: Oh, what is the initial temperature?

Task 3

Classmate: All right, did you guys get your final?
Partner 1: Yeah, it’s like 26 or 27.
Classmate: All right, good, good.
Neil: [Removes thermometer and places it in empty beaker.]
Partner 1: [Reads temperature from thermometer.]
Neil: So about 24?
Partner 1: 26.

**Tasks 4-5**

Partner 1: [Stirring.]
Partner 2: Wait, wait, stir it a little more, there’s some stuff at the bottom.
Neil: [Places thermometer back in solution.]
Partner 1: [Reading temperature from thermometer.]
Neil: [Holding thermometer in solution.]
Partner 1: Little bit more.

**Task 6**

Partner 1: [Reading temperature from thermometer.]
Partner 1: It’s about 27.
Neil: [Transfers thermometer from beaker with solution to empty beaker.]
Partner 1: [Makes calculations and records data.]
Partner 1: So it’s 3.6.

**Task 7**

Neil: So wait, you’re adding grams of HCl?
Partner 1: Okay, so the starting temperature is...
Partner 1: [Putting thermometer into solution.]
Neil: [Holding thermometer in solution.]
Partner 1: [To RT Nancy] Is this asking for the reactive HCl?
RT Nancy: It’s asking for the volume of the HCl, or the reaction. It says volume of one molar, so that should be liters, not grams, and we have one gram. Did Cl read exactly one gram?

**Task 8**

Partner 1: [Reading temperature from thermometer.]
Partner 1: It’s 23 degrees Celsius.
Neil: [Transfers thermometer from beaker with solution in it to empty beaker.]
Partner 1: Do we have to stir it? Do we have to stir?
RT Nancy: Yes.

**Task 9**

Partner 1: Can we put in the magnesium then?
Partner 1: Okay, so just hold this in there.
Neil: [Holding thermometer in solution.]
Investigator Commentary: While the time that Neil spent involved with performing laboratory actions was substantial, he had very little hands-on involvement other than holding the thermometer. The majority of the other types of equipment manipulations and chemical handling were accomplished by his lab partners. He was allowed to contribute only when his lab partners identified a task that they felt Neil could assist with. Minimal dialogue was contributed by Neil. His intellectual contributions to the completion of the lab goals were minimal.
Lesson 3 Analysis: Colligative Properties (I-Video)

Table 8-4: Lesson 3 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00.0 - 0:10.5</td>
<td>Working on computer</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>0:39.1 - 1:20.5</td>
<td>Transfers liquid with dropper</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>1:46.2 - 2:01.6</td>
<td>Obtains mass of new liquid</td>
<td>I</td>
<td>3</td>
</tr>
<tr>
<td>2:42.3 - 2:45.2</td>
<td>Hands test tube of liquid to partner</td>
<td>N</td>
<td>4</td>
</tr>
<tr>
<td>3:12.8 - 3:17.2</td>
<td>Inserts thermometer into test tube</td>
<td>I</td>
<td>5</td>
</tr>
<tr>
<td>3:17.2 - 4:36.5</td>
<td>Watches computer to observe temperature</td>
<td>I</td>
<td>6</td>
</tr>
<tr>
<td>4:36.5 - 4:45.3</td>
<td>Stirs solution in beaker</td>
<td>N</td>
<td>7</td>
</tr>
<tr>
<td>4:48.7 - 5:04.9</td>
<td>Starts data collection on computer</td>
<td>I</td>
<td>8</td>
</tr>
<tr>
<td>5:11.7 - 7:10.0</td>
<td>Stirs solution in test tube with thermometer</td>
<td>I</td>
<td>9</td>
</tr>
<tr>
<td>7:16.1 - 8:02.1</td>
<td>Stirring solution in test tube with thermometer</td>
<td>I</td>
<td>10</td>
</tr>
<tr>
<td>7:20.0 - 7:26.5</td>
<td>Working on computer</td>
<td>I</td>
<td>11</td>
</tr>
<tr>
<td>22:04.1 - 22:24.6</td>
<td>Cleaning up</td>
<td>N</td>
<td>12</td>
</tr>
</tbody>
</table>

Tasks 1-2

Neil: [Working on computer.]
Partner 1: Would you like to do the honors, the droppings of it? I’ll give you a dropper.
Neil: Yeah.
Partner 1: [Measuring out solution.]
Partner 1: That’d be cool.
Neil: Can you tell me how many drops?
Partner 1: 30 to 35.
Neil: [Inaudible.]
Partner 1: All right.
Partner 1: [Passes dropper to Neil.]
Partner 1: [Passes test tube of liquid to Neil.]
Neil: [Transfers liquid with dropper.]
**Task 3**

Partner 1: [Hands new test tube of liquid to Neil.]
Partner 1: Can you weigh that please? Wait, wrong one, that one. We need a mass on that.
Neil: [Obtains mass of new liquid.]
Partner 1: 23.1, oh, 23.2 grams, very good.

**Task 4**

Partner 1: Which is the, uh, test tube, the Na2SO4, and the [inaudible]?
Neil: Yeah, we’re on Part B.
Partner 1: Oh, can I have the thingamajig back? Appreciate it.
Neil: [Hands test tube of liquid to partner.]
Partner 1: [Picks up and then puts down the temperature probe.]

**Tasks 5-6**

Partner 1: Get ready to collect more information.
Neil: I’m going to go ahead and stick it in here.
Partner 1: Stick the thermometer in there, please.
Neil: [Inserts thermometer into test tube.]
Partner 1: And we’ll just let it sit like last time where it was and just collect it, do that every chance to get us perfect, and we’ll do the collect-every-10-second kinda thing.
Partner 1: [Watching computer to observe temperature.]
Neil: [Watching computer to observe temperature.]
Partner 1: Well, we’ll start the collection once it peaks out, okay?
Neil: So don’t worry about it until it peaks out... that looks like... when it starts going back down.
Partner 1: It’s still going up.

**Task 7**

Partner 1: Still going down, you can go down.
Neil: Do we need to agitate it?
Neil: [Stirs solution in beaker.]

**Tasks 8-9**

Partner 1: Yes, it’s peaked, it’s going down now, so we should restart, starting on collection, cause that way we can have just the downwards slope, ya know?
Neil: [Starts data collection on computer.]
Classmate: Are you stirring yours?
Partner 1: Yeah, we are now. We had to wait for it to peak out on the heat so that we could get the actual reading.
Partner 1: [Stirring solution.]
Partner 1: You stir.
Neil: [Stirs solution in test tube with thermometer.]

Tasks 10-11

Classmate: We’re at 19.1.
Partner 1: [Reading lab procedure.]
Partner 1: All right.
Neil: [Stirring solution in test tube with thermometer.]
Neil: [Working on computer.]
Partner 1: Apparently by the sound of them, we’re going to be here a while.
Partner 1: You can stop stirring.
Neil: Okay.

Task 12

Partner 1: Wash this in acetone?
Neil: [Cleaning up.]
Partner 1: [Cleaning up.]
RT Nancy: Okay, guys, we have to clean up.
RT Nancy: There’s isopropanol back here to rinse the test tubes and the thermometers.
RT Nancy: You need to unfreeze. Heat up your toluene so that it’s liquid.
Partner 1: [Cleaning up.]
Partner 1: What do you want with the ice and what not?
RT Nancy: Ice and what not can go down the drain.

Investigator Commentary: In this lesson, Neil was more involved in the hands-on lab activities of his group, including stirring solutions and measuring temperatures. However, the hands-on tasks were largely directed by his lab partner. The partner collaborated with Neil to obtain data and was very descriptive for Neil regarding how the data were plotting during collection. Neil also contributed intellectually to the completion of the lab goals.
Lesson 4 Analysis: Equilibrium (I-Video)

Table 8-5: Lesson 4 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:47.5 - 2:01.0</td>
<td>Washes the beaker</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>3:57.5 - 5:16.9</td>
<td>Works on SALS</td>
<td>I</td>
<td>2</td>
</tr>
<tr>
<td>5:36.2 - 5:43.2</td>
<td>Takes beaker from bench and smells it</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>13:03.1 - 13:42.1</td>
<td>Uses the notched syringe</td>
<td>I</td>
<td>4</td>
</tr>
<tr>
<td>13:47.9 - 13:55.3</td>
<td>Places test tube in the test tube rack</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>13:57.1 - 14:07.5</td>
<td>Cleans out notched syringe with water</td>
<td>I</td>
<td>6</td>
</tr>
<tr>
<td>14:14.7 - 14:52.3</td>
<td>Uses notched syringe to withdraw liquid and place it into a test tube</td>
<td>I</td>
<td>7</td>
</tr>
<tr>
<td>15:00.4 - 15:01.4</td>
<td>Hands test tube to lab partner</td>
<td>N</td>
<td>8</td>
</tr>
<tr>
<td>15:03.8 - 15:24.0</td>
<td>Uses notched syringe to place more liquid into the test tube</td>
<td>I</td>
<td>9</td>
</tr>
<tr>
<td>19:31.0 - 19:36.2</td>
<td>Empties notched syringe into the sink</td>
<td>I</td>
<td>10</td>
</tr>
<tr>
<td>36:32.4 - 36:41.1</td>
<td>Picks up notched syringe, places it in beaker, takes it out of beaker</td>
<td>I</td>
<td>11</td>
</tr>
<tr>
<td>36:41.4 - 36:51.4</td>
<td>Dispenses liquid from notched syringe into test tube held by Partner 1</td>
<td>I</td>
<td>12</td>
</tr>
</tbody>
</table>

Task 1

Partner 1: Can you wash whatever is in there?
Neil: [Washes the beaker.]
Partner 1: [Dries beaker.]

Task 2

RT Nancy: Since he refuses to put anything on there that I can see and since you don’t know Braille, one of those must turn it off, but I’m not sure which. And remember, you need a white piece of paper to calibrate the color white.
Neil: [Inaudible.]
Neil: [Works on SALS.]
**Task 3**

Partner 1: Hey, Neil, in the big beaker is a gigantic amount of HCl. Be very careful, it’s [inaudible].
Partner 1: [Places beaker on bench.]
Neil: It smells like acid. If you bring it up here, I’ll clock you.
Partner 1: [Inaudible.]
Neil: [Takes beaker from bench and smells it.]

**Tasks 4-6**

RT Nancy: Do you have silver nitrate poured out?
Partner 1: I didn’t even know there was silver nitrate.
Partner 1: What’s first?
Neil: Um, NaSCn.
Partner 1: NaSCn is this one. Two drops.
Neil: Which one?
Partner 1: NaSCn is this one. Two drops.
Neil: [Inaudible.]
Partner 1: Yeah, the five that are facing outward.
Partner 1: Yes, that’s because we have 12 molar HCl, which is as strong as it gets. We usually only end up using about a 0.1 molar or a one molar, which won’t really do much. A 12 molar, or we’re talking, let’s burn through the floor if we want.
Neil: This one? There’s enough in there, right?
Partner 1: Yeah, probably.
Neil: [Uses the notched syringe.]
Partner 1: [Hands test tube to Neil.]
Neil: Okay, here you go.
Neil: [Places test tube in the test tube rack.]
Partner 1: [Inaudible.]
Neil: [Cleans out notched syringe with water.]

**Tasks 7-9**

Partner 1: Two drops.
Partner 1: [Hands beaker of acid to Neil.]
Neil: [Inaudible.]
Neil: [Uses the notched syringe to withdraw liquid and place it into a test tube.]
Partner 1: It should all [inaudible] turning red.
Neil: Here you go.
Partner 1: [Inaudible.]
Neil: [Hands test tube to lab partner.]
Neil: [Uses notched syringe to place more liquid into the test tube.]
Partner 1: Good enough.
Task 10

Partner 1: [Places test tube back into the rack.]
Partner 1: It’s all [inaudible] or less than this one.
Neil: [Empties notched syringe into the sink.]
Neil: [Walks off screen.]
Neil: [Inaudible.] I have no idea what’s going on.

Tasks 11-12

Neil: [Picks up notched syringe, places it in beaker, takes it out of beaker.]
Neil: Unlock this one.
Partner 1: It is.
Partner 1: Here now.
Partner 1: Have to guide it in so I don’t die.
Partner 1: [Holds a test tube containing a tan color in one hand. Uses other hand to
guide Neil’s hand toward test tube.]
Neil: [Dispenses liquid from notched syringe into test tube held by Partner 1.]

Investigator Commentary: In this lesson, Neil utilized the SALS to collect color change
information. He had some difficulty using this tool. There was a lack of print labels on
the device, and an element of frustration was exhibited by RT Nancy due to this fact. Neil
was involved with the group partner in the handling of solutions but primarily just with
using the notched syringe. The lab partner was careful to make sure Neil had enough
solution in the various beakers he used before extracting solutions from the beakers to go
into the various test tubes. Neil’s intellectual contributions to the experiment were
minimal. Neil was an integral part of his lab group, but contributed mostly with physical
tasks and less so with intellectual discussion.
Lesson 5 Analysis: Titration (I-Video)

Table 8-6: Lesson 5 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00.0 - 1:32.2</td>
<td>Calibrating drip speed for drop counter</td>
<td>I</td>
<td>1</td>
</tr>
<tr>
<td>3:08.6 - 3:26.7</td>
<td>Working on computer</td>
<td>I</td>
<td>2</td>
</tr>
<tr>
<td>4:39.6 - 4:43.9</td>
<td>Hands beaker to partner</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>5:56.8 - 6:02.5</td>
<td>Adjusting setup</td>
<td>N</td>
<td>4</td>
</tr>
<tr>
<td>8:20.3 - 8:26.6</td>
<td>Pouring liquid into top of buret</td>
<td>I</td>
<td>5</td>
</tr>
<tr>
<td>10:28.7 - 12:09.6</td>
<td>Weighing flask and working on computer</td>
<td>I</td>
<td>6</td>
</tr>
<tr>
<td>14:49.4 - 17:20.7</td>
<td>Setting up pH probe</td>
<td>I</td>
<td>7</td>
</tr>
<tr>
<td>27:11.2 - 28:57.9</td>
<td>Running titration</td>
<td>I</td>
<td>8</td>
</tr>
<tr>
<td>30:34.5 - 31:24.3</td>
<td>Setting up new titration system</td>
<td>I</td>
<td>9</td>
</tr>
<tr>
<td>35:13.0 - 35:27.9</td>
<td>Pouring liquid into titration setup</td>
<td>I</td>
<td>10</td>
</tr>
<tr>
<td>36:31.5 - 36:44.9</td>
<td>Setting up titration</td>
<td>I</td>
<td>11</td>
</tr>
<tr>
<td>37:52.7 - 38:09.4</td>
<td>Starting titration</td>
<td>I</td>
<td>12</td>
</tr>
<tr>
<td>38:13.8 - 38:17.6</td>
<td>Stops titration</td>
<td>I</td>
<td>13</td>
</tr>
<tr>
<td>39:03.3 - 39:19.0</td>
<td>Adjusting drop speed</td>
<td>I</td>
<td>14</td>
</tr>
<tr>
<td>51:22.7 - 51:24.3</td>
<td>Adds one more drop</td>
<td>I</td>
<td>15</td>
</tr>
<tr>
<td>56:24.1 - 56:37.0</td>
<td>Switching beakers in titration setup</td>
<td>N</td>
<td>16</td>
</tr>
<tr>
<td>56:45.9 - 57:10.8</td>
<td>Removes pH probe from setup, cleans it in solution, and returns it to apparatus</td>
<td>I</td>
<td>17</td>
</tr>
</tbody>
</table>

Task 1

Neil: [Calibrating drip speed for drop counter.]
Partner 1: You know what else might help?
Neil: What?
Partner 1: Grab the water.
Neil: Am I...?
Partner 1: You are now anyway, you weren’t, but you’re letting it out way too fast.
Neil: Yeah, I know, I opened it.
Partner 1: Oh, that will do it.
Neil: Is anything coming out?
Partner 1: Uh, it’s pouring instead of dripping.
Neil: Is it dripping now?
Partner 1: Yeah, enough water.

Task 2

Partner 1: I’ll run and grab the stuff.
Partner 1: [Gathering materials.]
Neil: [Working on computer.]

Task 3

Partner 1: Are we good and calibrated?
Neil: Uh, is that at zero?
Partner 1: Okay, pass me the beaker over there.
Neil: [Hands beaker to partner.]

Task 4

Neil: What exactly are you pouring?
Partner 1: I put 100 mL of vinegar into this thing, and this one will go on the bottom underneath that. Okay?
Partner 1: [Gathering materials.]
Neil: [Adjusting setup.]

Task 5

Partner 1: Um, we’re supposed to condition the buret, but since we’re using water, it should be fine.
Partner 1: There’s nothing about weighing anything, but we might be doing something later, like once it changes....
Partner 1: You can pour that in the top over there.
Neil: [Pouring liquid into top of buret.]

Task 6

Partner 1: Um, there’s two empty Erlenmeyer flasks right next to you. Grab one of them and put it on the weight, or the scale over there, and we have to weigh it.
Neil: [Weighing flask and working on computer.]
Partner 1: Pass me the, uh, flask after you are done weighing it.
**Task 7**

Partner 1: I put some water in, and then you get the phenolphthalein, all right?
Partner 1: Oh, here.
Neil: Uh, not using phenolphthalein ... pH probe ... color detector.
Neil: [Setting up pH probe.]
Partner 1: No, um, oh, oh, gotcha, gotcha, gotcha, gotcha.
Partner 1: [Filling flask with water.]
Partner 1: I want to see how this thing works anyway.

**Task 8**

Neil: I hit “start collect.”
Neil: I guess we might as well ... start this and then start dropping and then start collection.
Partner 1: Only go for a couple drops, though.
Partner 1: It might be, it might be part of the drop collector thing.
Neil: [Running titration.]

**Task 9**

Partner 1: Can we get another sample started with vinegar?
Partner 1: [Gathering materials.]
Partner 1: Can we get another beaker?
Partner 1: All right, uh, we’ll just set this one down.
Neil: [Setting up new titration system.]

**Task 10**

Partner 1: I remember what happened now. We only got a little bit and we poured the entirety of it in. Don’t pour the entirety of it in or it will spill.
Neil: It will spill.
Partner 1: Tell you when to stop, all right?
Neil: [Pouring liquid into titration setup.]
Partner 1: Stop, stop.
Partner 1: All right, thank you.

**Task 11**

Neil: [Setting up titration.]
Neil: Um, so we’re just starting, starting.
Partner 1: Wait, hit the “start collection” first.
Neil: Yeah, I will, I will.
**Task 12**

Partner 1: Did you, oh, you didn’t switch it back to the pH ... mass scale ... mass scale on there.
Neil: Oh, okay.
Partner 1: All right, now we’re good.
Neil: [Starting titration.]
Partner 1: All right, let’s start this up.

**Task 13**

Neil: Is it dropping?
Partner 1: Yeah, but it’s not counting drops.
Partner 1: We should probably stop it.
Neil: [Stops titration.]

**Task 14**

Partner 1: Oh, it’s counting, counting some of them. What’s up?
Neil: [Adjusting drop speed.]
Partner 1: Slow it down.
Partner 1: There we go.
Partner 1: No, that’s fine.

**Task 15**

Partner 1: 26.4 is the final volume, but due to the pH difference we could’ve added an extra drop.
Partner 1: Give it a try, actually, add one more drop to that, see if it does anything.
Partner 1: Just a real quick drop.
Neil: [Adds one more drop.]

**Tasks 16-17**

Partner 1: All right, trade me beakers, all right?
Partner 1: Cause you still have the old beaker there, so trade.
Neil: [Switching beakers in titration setup.]
Partner 1: Wow, that’s definitely not what the pH is.
Neil: [Removes pH probe from setup, cleans it in solution, and returns it to apparatus.]

*Investigator Commentary:* Neil was very involved with the hands-on aspects of this lab activity. He used the ILAB/Vernier tool interface to help with the acid base titration. He
physically manipulated the equipment setup and the probes. He also participated more in
the dialogue regarding how the experiment was carried out, and was more directly
responsible for how trials were conducted. His intellectual contributions to the
discussions were less than those of his partner but greater than those seen in earlier
lessons. Neil’s contributions were valued by his lab partner. His partner also expressed
genuine interest in how the ILAB tools functioned. Neil was more incorporated into the
lab group’s activities in this experiment, and the range of his involvement was
significantly greater than that seen in the N-videos or the earlier I-videos.
Graphic Analysis of Video Data

The data illustrated in Figures 8-1 and 8-2 show the percent of time engaged (PTE) for the BLV student and his sighted lab group partners in performing laboratory-goal-directed actions during laboratory lessons, as described in Chapter 4. For lessons involving more than one sighted partner, the separate PTEs for the partners were combined. To help in understanding the graphical data, instances of multiple partners are noted in the text describing the PTE results for the individual lessons. Sighted students may have rotated from lab to lab. Neil is indicated in blue, and the sighted partners are indicated in red. Figure 8-1 shows the results of the two lessons conducted without the use of ILAB tools, and Figure 8-2 shows the results of the three lessons conducted with ILAB tools.

In Lesson 1, Neil exhibited 7.2% PTE, while in Lesson 2 he exhibited 65.5%. In both these lessons, Neil had two partners. The wide difference in his PTEs between the two labs may have been highly dependent on the content in question. That is, Lesson 2 may have been relatively adaptable for him while Lesson 1 may not have been. Also, Neil was nervous about the use of corrosive chemicals in Lesson 1. For the I-videos, Neil’s hands-on involvement was greater than 50% for all the lessons and showed a sustained improvement from lesson to lesson. The presence of the ILAB tools may have allowed him to participate more equally with his sighted partners. In Lesson 3, his observed PTE was 55.7%, Lesson 4 was 62.2%, and Lesson 5 was 82.6%. The increased numbers may have been a result of his use of the ILAB tools and may also reveal some growth in efficacy as time went on. His overall performance was much higher during the lessons with ILAB tools as compared to the lessons without ILAB tools.
Figure 8-1: Percent of Time Engaged During N-Video Lab Sessions for BLV Student and Sighted Partner

Figure 8-2: Percent of Time Engaged During I-Video Lab Sessions for BLV Student and Sighted Partner
Video Analysis Rubric Results

Table 8-7 shows the results of the ILAB video analysis rubric, which was designed to collect information regarding the levels of acceptance of the BLV students into their lab groups. (See the explanation in Chapter 4 and the rubric questionnaire in Table 4-5.) The three raters made numerical rankings of each of the eight rubric items for each of the five videos of Neil included in this study. The lessons conducted without ILAB tools are labeled as “N,” while the lessons conducted with ILAB tools are labeled as “I.” The three raters are identified as “EE” for the external evaluator, “IR” for the independent rater, and “IS” for the investigator in this study. For the yes/no items (A, B, E), “yes” is coded as 1 and “no” is coded as 0. For the Likert-scale items (C1-C4 and D), “strongly agree” is 5, “no opinion” is 3, and “strongly disagree” is 1.

Table 8-7: Video Analysis Rubric Results

<table>
<thead>
<tr>
<th>Rubric Item</th>
<th>Lesson 1 (N)</th>
<th>Lesson 2 (N)</th>
<th>Lesson 3 (I)</th>
<th>Lesson 4 (I)</th>
<th>Lesson 5 (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EE</td>
<td>IR</td>
<td>IS</td>
<td>EE</td>
<td>IR</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>C2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>C3</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>C4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 8-8 summarizes the patterns seen in Table 8-7, indicating the total number of occurrences found for each of the numerical rubric rankings and the averaged N vs. I scores for each rubric item. For the binary (yes/no) items, high inter-rater agreement was observed, whereas greater variability was seen in the Likert-scale ratings. This is consistent with the inter-rater reliability coefficients discussed in detail in Chapter 10.

Table 8-8: Patterns Observed with the Video Analysis Rubric

<table>
<thead>
<tr>
<th>Rubric Item</th>
<th>Summary of Scores</th>
<th>Average N</th>
<th>Average I</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10 ones of 15 possible</td>
<td>0.17</td>
<td>1.0</td>
</tr>
<tr>
<td>B</td>
<td>10 ones of 15 possible</td>
<td>0.17</td>
<td>1.0</td>
</tr>
<tr>
<td>C1</td>
<td>3 fours, 8 threes, 1 two, 3 ones</td>
<td>1.8</td>
<td>3.3</td>
</tr>
<tr>
<td>C2</td>
<td>14 fours, 1 three</td>
<td>4.0</td>
<td>3.9</td>
</tr>
<tr>
<td>C3</td>
<td>6 threes, 7 twos, 2 ones</td>
<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td>C4</td>
<td>1 four, 4 threes, 10 twos</td>
<td>2.7</td>
<td>2.2</td>
</tr>
<tr>
<td>D</td>
<td>8 fours, 2 threes, 3 twos, 2 ones</td>
<td>1.8</td>
<td>3.9</td>
</tr>
<tr>
<td>E</td>
<td>9 ones of 15 possible</td>
<td>0.00</td>
<td>1.0</td>
</tr>
</tbody>
</table>

For items A and B, agreement between the raters was perfect except for Lesson 1. The averaged rater scores for the N-lessons show that the BLV student was not significantly involved in discussions related to the completion of the laboratory goal and the sighted students did not accept the contributions of the BLV student, respectively. The story for the I-lessons is very different, however: There is perfect agreement among the raters that the negative situation was reversed for items A and B, and that the BLV student was involved in discussions and his contributions were accepted. Perfect rater agreement occurred for item E with all lessons, with the BLV student found to be not included in the collaborative participation of the group during the N-lessons but included
in the collaborative participation during the I-lessons. Items A, B, and E all show a much higher level of inclusion of the BLV student during the ILAB lessons.

In C1, the averaged rater scores rank the BLV student substantially lower for Lessons 1 and 2 than for Lessons 3-5, indicating that Neil experienced greater interest during the ILAB lessons. However, substantial rater disagreement is seen for Lessons 1 and 2, with scores ranging from 1 to 3. In the case of item C2, the BLV student’s level of interest essentially stayed the same for all five lessons, with very high agreement among the raters. For item C3, an increase in interest over the course of the individual experiments was not observed for the BLV student in any of the lessons. Lessons 1 and 2 exhibited the most disagreement for C3, with ratings ranging from 1 to 3, but no rater scores higher than 3 were found for Lessons 3-5 either. The averaged rater scores for C3 show that the BLV student’s interest level did not increase during the course of any of the lessons. It should be noted that for item C3, the investigator in this study tended to rank both the N-lessons and I-lessons higher than did the other raters; however, the investigator acknowledges that, as a blind person, he may not have been able to observe various pertinent details observed by the other raters, both of whom were sighted. Item C4 indicates the BLV student’s level of interest in the lessons did not decrease over the course of any of the lessons, although there is substantial rater disagreement for Lesson 2.

For rubric item D, the techniques used by the BLV student were perceived by his sighted lab partners as being more beneficial during Lessons 3-5 than during Lessons 1 and 2. Rater disagreement of two levels are seen for Lesson 1, with rankings ranging from 1 to 3, but rater agreement for Lessons 3-5 is very high.
For the Likert-scale items, all major disagreements between raters – for which the difference was at least two levels – occurred in Lessons 1 and 2. Greater agreement among raters was observed for the ILAB lessons. None of the lessons had complete agreement across all rubric items. Rater disagreements of only one level within individual Likert-scale rubric items may have been due to small variations in interpretation and/or perception, whereas disagreements of greater than one level may have been at least partially caused by unintentionally ambiguous terminology in the rubric itself, as discussed in Chapter 10.

**Summary**

At least partially due to his fear of injury in the laboratory, Neil was overall more involved with hands-on activities in the lessons incorporating the ILAB tools than in those not incorporating the ILAB tools. The various ILAB tools helped him to safely participate more than he would have done otherwise. He also had some residual vision that complemented his use of the tools. Additionally, he used a software program known as ZoomText that enlarged onscreen print, which complemented his use of JAWS. However, he depended upon the JAWS/Logger Pro interface to conduct data collection.

Neil had taken first-year chemistry with RT Nancy during the previous school year and was permitted to use the ILAB tools during that experience. For the current investigation, he demonstrated a good understanding of how the tools worked, and his comfort with computers and the JAWS/Logger Pro interface was noted. Neil was the primary caregiver for a family member, and thus did not have time to devote to more practice with ILAB tools and lab skills, but he was able to demonstrate an increasing
level of efficacy with the technology as well as increased involvement with laboratory
tasks (both in PTE and range of tasks) as the school year progressed. His SAI II scores
also increased substantially from pre-school-year to post-school-year.

Because Neil was concerned about getting injured in the laboratory, he did not
feel comfortable working on his own, but preferred working as a member of a group. The
tasks in which Neil engaged while using the ILAB tools were clearly directed toward
conducting the laboratory procedures; whereas when he did not have the use of the tools,
he was sometimes a passive observer. This greater engagement during the ILAB lessons
can be seen in several of the data sets, including that for the video analysis rubric. In fact,
as noted in some of the transcripts, the other students raised concerns for Neil when he
was not allowed to use the ILAB tools; they did not understand the educational research
that was being conducted.

RT Nancy indicated positive feelings toward Neil learning chemistry. She took it
upon herself to try to learn how the ILAB tools functioned so she could better assist Neil
in class. Although her overall teaching experience was not as positive, her commitment to
Neil’s learning was apparent in her interview.

As indicated by improvements in his PTE data, SAI II scores, and rubric scores,
Neil appeared to benefit from the ILAB tool intervention regarding his hands-on
laboratory participation, attitude toward science, and acceptance into his lab group. This
is also illustrated in the Video Task Analysis section, which illustrates the increasing
level and range of his involvement over time.
Chapter 9

Twin Pines High School Case Study

Twin Pines High School (a pseudonym) is a public charter institution located in a major metropolitan Midwestern city in the United States. The school’s mission statement indicates a commitment to building character and developing productive citizens through a strong academic program that works in partnership with the families and community. Twin Pines was founded in 1999 and includes grades nine through twelve. The school strives to instill in its students a positive attitude to help empower them to succeed in their endeavors.

Demographics of School

At the time of this study, Twin Pines enrolled approximately 200 high school students, with an average class size of 25. Its student body was 53% female and 47% male. Reported student racial breakdown was 64% white, 20% African-American, 7% Asian, 7% Hispanic, and 1% Native American. Seventeen percent of the students were eligible for free or reduced-price lunch. Approximately 5% were enrolled in special education services. The school had 19 faculty members, about half of whom had master’s degrees. Two of the faculty members were science teachers.

Background of Student

Emily (a pseudonym) was a sophomore enrolled in a chemistry class. She was 16 years old and lived in a single-income family. Her father worked for a major
manufacturing company, and her mother was a homemaker and the primary caregiver. Emily was adopted from an Asian country as an infant and lost her sight at age two. She described her vision as being able to perceive light only. She was unable to visually recognize shapes or large print and indicated she was not able to see colors for identification purposes. Emily used a white cane for travel and demonstrated competency in reading and writing Braille. She used a HumanWare BrailleNote electronic note-taker device in all of her classes and in everyday life. She also used a laptop computer equipped with JAWS for her classwork. Emily had the assistance of a teacher’s aide provided by the school district. This person’s primary responsibility was to help with ancillary tasks and to ensure Emily was not at risk from environmental hazards in her classes.

Emily said she did not have ideas regarding her possible employment or career path after high school. She reported that she wanted to pursue higher education but did not know where at the time. She had previously taken an earth science class in middle school and a general physical science class during her freshman year of high school. The physical science class had included a laboratory component for which she worked in lab groups consisting of three to four students. She had tended to work with rotating lab partners throughout that school year, with the teacher choosing the partners. Emily indicated some apprehension about her upcoming chemistry class because she had experienced difficulty understanding what had gone on during her physical science laboratory sessions and had experienced a high dependency on her earlier lab partners to describe the lab activities.
**Background of Teacher**

Emily’s teacher, given the pseudonym of TT Lindsey (Twin Pines teacher Lindsey) was a recent graduate of a master’s degree program in science education at a major four-year institution in a southern U.S. state. She had obtained a bachelor’s degree in chemistry from a Midwestern four-year university. Her job at Twin Pines was her first full-time employment since completing her student teaching requirement. She had been teaching for fewer than five years at the time of this study. Emily was TT Lindsey’s first blind student. TT Lindsey had worked with Emily during the previous school year as her physical science teacher.

**Classroom Resources**

Lindsey’s classroom served both as a lecture space and a laboratory. Her physical laboratory resources were limited to one sink and working on regular tabletops. Class periods at the school were only 50 minutes in length, which limited the types of activities that were possible. Storage space for computers and other laboratory equipment was also in short supply. For activities that required the use of a more extensive laboratory, the class traveled to a nearby community college that had partnered with the high school; extended class periods were scheduled for this purpose. The college also provided access to their stockroom and chemical disposal services. For lab sessions at the community college, Emily had to bring her laptop computer and the ILAB tools.
Relationship between Investigator, Teacher, BLV Student, and Parents

The investigator had frequent correspondences with the teacher and the student’s mother, and infrequent correspondences with her father. Communications primarily took place via email, supplemented by occasional phone calls and onsite visits. The teacher also took part in conference calls with the other ILAB teachers participating in this study. These conference calls occurred approximately every 60 days and gave the ILAB teachers a chance to ask each other questions and share their experiences. The conference calls also served as a way for the investigator to receive feedback regarding how the ILAB tools were being implemented in the various classrooms.

TT Lindsey raised concerns that the investigator was communicating with Emily and her mother without TT Lindsey’s knowledge. Such communications occurred on several occasions when Emily’s mother contacted the investigator to ask questions about ILAB tool functionality. This situation led to a somewhat negative relationship between the investigator and the teacher, which may have impacted the teacher’s willingness to work directly with Emily on implementing the ILAB tools in the chemistry curriculum. It also possibly affected the teacher’s responses during her post-year interview. TT Lindsey told the investigator that she believed Emily needed to take responsibility for learning how to use the ILAB tools, as she felt it was not fair to take time away from her other students to determine how best to adapt the laboratory curriculum to accommodate Emily’s technology.

Toward the last quarter of the school year, TT Lindsey requested assistance from the ILAB team for direct involvement with lab procedure modifications. The modifications were provided to TT Lindsey in advance of the pertinent lab sessions with
Emily. Whenever possible, supplies were also provided for experiments requiring larger volumes of chemicals for Emily than for the other students as a result of the ILAB tools not being fully useable in microscale environments. Microscale lab activities use only drop amounts of chemicals, whereas ILAB tools are designed for macroscale environments.

The mother also shared concerns with the investigator as to how Emily was using the ILAB tools. Therefore, an additional face-to-face training session was provided to Emily at mid-school-year, during which Vernier Software & Technology products were described and explanations provided on using the JAWS hotkeys in conjunction with the Logger Pro data collection software. Although Emily appeared to pick up on the use of the tools quickly, she was easily distracted, which was directly observed by the investigator when working with her. No field notes were taken by the investigator at this second training, thus many such interactions are undocumented and are from the investigator’s recollections.

Emily rarely communicated with the investigator either via telephone or email. Most communications were with her mother and teacher; therefore, all modifications for Emily were based on what others thought she needed. Her lack of feedback was a limitation in customizing the ILAB experience for her. In general, she exhibited a preference for being a passive learner; i.e., preferring to be acted upon rather than initiating actions.
Interview Data

The following are excerpts and/or summaries of dialogue between the investigator and the BLV student, and between the investigator and the teacher. The questions asked were based on the standard interview scripts for the ILAB study (Tables 4-1, 4-2, 4-3); follow-up questions for clarification were also asked, dependent on the student’s or teacher’s responses to the initial queries. These particular questions were chosen for analysis because of their significance to the incorporation of the BLV student into lab groups, her efficacy with the ILAB tools, and her interest in science. Commentary from the investigator follows the excerpts/summaries for each interview.

Excerpts, Summaries, Commentary: Pre-School-Year Student Interview

Have you been in any mainstream science classes up to this point?

“In junior high I was in earth science, and in ninth grade I was in physical science.”

Did any of those classes have a lab component to them?

“Physical science I think did, because half of it was chemistry.”

Did you work in groups or did you work on your own?

“It was usually about three to four [students].”

Do you have any excitement or apprehension about your upcoming chemistry class?

Emily indicated she was “a little worried because there will be more labs.” She does not enjoy labs because she feels she “can’t really do a lot.”
Investigator Commentary: Emily perceived herself as limited in what she was capable of doing during the laboratory component of her upcoming chemistry class, based on her previous laboratory experiences. She did express some optimism about participating more fully in the chemistry class. She had worked in lab groups prior to the school year in question, and thus was familiar with this type of arrangement.

Excerpts, Summaries, Commentary: Post-School-Year Student Interview

What was your favorite part of chemistry class? Did you like the lab part of the class? Emily indicated she was interested in topics such as nomenclature, the naming of compounds, and the elements. She said she thought the experiments in lab were “cool.”

Do you think your visual impairment made working in the lab more difficult? “Not really more difficult ... maybe sometimes you can’t participate as much but it’s not really difficulty.”

When you’re working as part of a team, do you tend to work on the things that are easiest for you to do?” “I think I do. It’s just a habit, I guess.”

Do you think this class helped you to realize that you could do science and that it wouldn’t be too hard for you even though you didn’t necessarily like the class material? “I didn’t like it, but I think it’s, it’s challenging but not impossible.”

Do you think this class helped or hindered your desire to be a scientist? “This particular class probably hindered my desire to be a scientist.”
Investigator Commentary: Emily stated the labs were the coolest part of her chemistry learning experience. She enjoyed having some level of hands-on participation as a result of using the ILAB tools. However, she indicated a lack of enthusiasm for going beyond the activities she felt comfortable doing. The textbook was easier for her to comprehend since all the material was readily available to her and she could learn at her own pace, whereas in the laboratory, she was not in control of the information she was given. She was dependent on her lab partners and teacher to provide her with the necessary information during lab sessions. This was not enjoyable for Emily. Her comment that the ILAB experience had hindered her interest in science indicated that the hands-on involvement provided through ILAB participation did not motivate her to consider science as a possible profession.

Excerpts, Summaries, Commentary: Post-School-Year Teacher Interview

Did Emily work with the same kids the whole school year?

“No.”

Did Emily tend to vary what tasks she performed, or did she find a niche that she felt comfortable with and tried to stay with that as long as she could?

“Neither. Emily really only gets involved to the extent that her partners push her to get involved. So if she has partners who say, ‘Why don’t you do this?’ or ‘We’ll wait for you,’ then she will do something, but she’s not vocal. She does not initiate communication with her partners no matter what partner she has. If it were totally up to her, she could very easily go through an entire lab without doing anything.”
How well do you think Emily was able to participate in her lab groups?

“She was very capable of collecting data. I think just looking at the equipment alone, if it was functioning, then she could very easily make a significant contribution. Personally speaking, she is not a very outgoing student and so her contribution is minimal and is based on prompting from others. In summary, it wasn’t like she wasn’t able to contribute, but I would say she often chooses to not contribute.”

Did you notice an increase in Emily’s self-efficacy with the equipment as the year progressed?

TT Lindsey indicated that Emily became more comfortable with the ILAB equipment over time but that getting it running occasionally posed a challenge. “If everything goes smoothly and she has one device that she’s familiar with, then she can deal with that device just fine.” However, Emily had difficulty managing two tools at a time. For example, in the specific heat lab, “We used the temperature and the balance, and she didn’t know how to go back and forth in terms of like the data. You know what I mean? To use the temperature probe one minute and the balance the next. Her familiarity with the Logger Pro program was minimal but in terms of actually using the devices, if it was a device she had used a few times already, then, yes, she was more comfortable with it, and can use it more easily.”

From your perspective, how well did Emily work with the other students in the class?

“She’s not very vocal, so not really. She doesn’t really initiate much communication.”

Investigator Commentary: Emily was often passive toward lab activities. Her participation was very dependent on her lab partners. If they encouraged her to do a task,
she would participate. Otherwise, she rarely carried out tasks. Since partners rotated from lab to lab, Emily’s levels of participation were highly variable. TT Lindsey observed that Emily’s self-efficacy with the tools increased the more she used the same tools, but that limitations in learning were exhibited with tools she had not previously used. TT Lindsey indicated some frustration with this attribute of Emily’s. She also indicated the ILAB tools were not always functional, leading to possible frustrations both for the teacher and the student, and sometimes limiting Emily’s participation in lab activities. TT Lindsey conveyed some sense of frustration with the ILAB project and the investigator.

**SAI II Survey Data Pre/Post School Year**

Emily’s SAI II survey data appear in Table 9-1. The table indicates the six attitudinal constructs, as discussed in Chapter 4. The Likert score totals for each construct are from the 40 questions in the SAI II instrument (see Table 4-4 in Chapter 4), with positive questions categorized as “A” and negative questions categorized as “B.” The “B” questions were reverse-coded for point values, meaning that higher scores indicate better attitudes both for the “A” and “B” questions, as described in Chapter 4. At the bottom of the table are total shifts in attitude for all “A” items and all “B” items, and a total for “A” and “B” together.

Emily exhibited very little change in attitude toward science from the pre-school-year survey to the post-school-year survey, with an attitude improvement of 2 points for construct #2, and 1 point each in constructs #1, #4, and #6. Construct #5 declined by 3 points, and no change was seen for construct #3. The results combine for an overall improvement in attitude of just 2 points. Her overall attitude toward science was
somewhat better than neutral/undecided, with a pre-year “all AB” score of 137 and post-year of 139.

Table 9-1: SAI II Data for Emily, Pre/Post School Year 2007-08

<table>
<thead>
<tr>
<th>Attitudinal Construct Scores</th>
<th>Pre-Year</th>
<th>Post-Year</th>
<th>Difference Pre/Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-A</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>1-B</td>
<td>12</td>
<td>13</td>
<td>+1</td>
</tr>
<tr>
<td>2-A</td>
<td>12</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>2-B</td>
<td>9</td>
<td>11</td>
<td>+2</td>
</tr>
<tr>
<td>3-A</td>
<td>11</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>3-B</td>
<td>11</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>4-A</td>
<td>7</td>
<td>9</td>
<td>+2</td>
</tr>
<tr>
<td>4-B</td>
<td>12</td>
<td>11</td>
<td>-1</td>
</tr>
<tr>
<td>5-A</td>
<td>10</td>
<td>7</td>
<td>-3</td>
</tr>
<tr>
<td>5-B</td>
<td>12</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>6-A</td>
<td>14</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>6-B</td>
<td>17</td>
<td>18</td>
<td>+1</td>
</tr>
<tr>
<td>All A</td>
<td>64</td>
<td>63</td>
<td>-1</td>
</tr>
<tr>
<td>All B</td>
<td>73</td>
<td>76</td>
<td>+3</td>
</tr>
<tr>
<td>All AB</td>
<td>137</td>
<td>139</td>
<td>+2</td>
</tr>
</tbody>
</table>
Overview of the Five Laboratory Lessons

This section contains synopses of what occurred in each of the five audio-video-recorded laboratory lessons. The lessons were part of the school’s regular curriculum. The following descriptions were written from the lesson transcripts. The synopses are not intended as complete representations of activities during each lesson, but rather are intended to provide readers with an idea of what the BLV student experienced. Short descriptions regarding how the BLV student interacted with her group partners are also included. Lab groups varied in size from lesson to lesson, comprising two or more people. Only the lab partners with whom Emily had the most communications and interactions are noted in the following synopses.

Please note that while the lessons not incorporating the ILAB tools are listed first, it was not by design that these lessons chronologically preceded those with ILAB tools. However, it is by design that the two N-lessons are chronological in relationship to each other, as are the three I-lessons. The I-lessons are listed in the order in which they actually occurred to better illustrate the BLV student’s progress, if any.

Lesson 1 Synopsis: Flame Test (N-Video)

This experiment involved placing different salts into a flame and noting the results. For each salt in turn, Q-tips were first dipped in methanol and then into the salt. Each Q-tip was next held in the flame of a Bunsen burner, and the resulting color of the flame was noted. TT Lindsey was highly solicitous of Emily’s participation, and prompted and directed Emily’s actions. She helped the BLV student operate the Bunsen burner, guided her hand to the containers of chemicals, and told her step by step what to
do. Emily’s lab partner likewise urged her participation. Emily was cooperative but exhibited few unprompted actions or utterances. (Note: This lesson was conducted in the local community college chemistry laboratory.)

**Lesson 2 Synopsis: Solubility and Precipitation (N-Video)**

TT Lindsey explained to her students the importance of taking note of the color of the first chemical before adding a second chemical, since a color change would indicate a chemical reaction between the metals in the solution. Before getting started on the experiment, Emily was not allowed by TT Lindsey to thoroughly feel the well plate because the teacher was concerned the plate might have been contaminated with chemicals. Instead, TT Lindsey showed Emily the indentations on the bottom of the plate. The lab partners added the drops of different chemicals to the wells while Emily recorded data on her BrailleNote. At the end of the experiment, the color changes of the solutions and the precipitates were discussed by Emily’s partners with minimal input from Emily. (Note: This lesson was conducted in the Twin Pines classroom.)

**Lesson 3 Synopsis: Hydrate (I-Video)**

TT Lindsey instructed her students in using the Bunsen burner. A teacher’s aide helped Emily turn on the gas jet. TT Lindsey told the students to adjust the ring stand and the crucible while putting the Bunsen burner off to the side. Emily examined the tongs and picked up the crucible with them. She put the crucible on the ring stand using the tongs and waited five minutes for it to heat up. While waiting, she troubleshooting Logger Pro on her computer. Next the crucible was allowed to cool, and Emily weighed it on the
balance with the help of the lab partner. Then about one gram of copper sulfate was
added to the crucible. Emily’s partner placed the crucible on the ring stand and heated it
for five minutes, noting a color change to white. The partner weighed the crucible a final
time and observed how much water had been removed from the copper sulfate through
determining the loss of mass. (Note: This lesson was conducted in the local community
college chemistry laboratory.)

Lesson 4 Synopsis: Specific Heat (I-Video)

TT Lindsey tried to get Emily more involved by giving her options of activities
for which she could be in charge. Emily chose to use the thermometer to take temperature
readings while her partner set up the experiment. Emily’s partner encouraged her to
engage in the activities by showing her all the equipment for the experiment in advance
and letting her pour the liquid into the beaker. During the experiment TT Lindsey
commented on the procedures for this lesson, pointing out that the students should avoid
common mistakes such as putting the lead in too early, before the water could reach the
boiling point, which could give the students errors in their data. During the recording of
the temperature of the water and lead, there was some confusion between Emily and her
lab partner regarding which temperature they were recording. (Note: This lesson was
conducted in the local community college chemistry laboratory.)

Lesson 5 Synopsis: Le Chatelier’s Principle (I-Video)

At the beginning of the experiment, while Emily’s partners were setting up the
procedure including adding the iron (III) chloride into the beaker, she had problems using
the SALS. Emily claimed that the instructions for using the SALS didn’t clearly explain how to operate the various functions of the instrument such as starting the sensor and storing readings in memory. When inserting the light sensor into the test tube, Emily needed some assistance from her lab partners to hold the sensor steady while she troubleshooted the functions of the SALS. After the experiment, Emily typed into her computer the color changes of the chemical reactions, as provided by a lab partner’s observations. TT Lindsey explained how to properly dispose of each chemical in the test tubes and advised Emily to ask the investigator about the double memory function of the SALS. (Note: This lesson was conducted in the Twin Pines classroom.)

**Video Task Analysis for Each Lesson**

The following five tables (9-2 through 9-6) were constructed to classify the types of tasks performed by Emily within each lesson. Excerpts from the transcripts of the corresponding lab group actions and dialogue are included following each table. The time stamp for each task, a description of the task performed, whether or not the task involved ILAB tools, and the task number (assigned consecutively for each chronological, discrete task that appears in each table, indicated so as to relate individual tasks in the tables to the appropriate transcript excerpts) are shown. (Note: Sometimes working on the computer is categorized as an ILAB-tool task and sometimes as a non-ILAB-tool task; the selection of “I” or “N” was based on whether the computer was being used along with an ILAB tool to take a data point or simply to take notes, perform calculations, or troubleshoot the computer.) As explained in Chapter 4, not all actions in the video task analysis were necessarily directed toward laboratory goals.
The selected tasks are not inclusive but were chosen as illustrative to provide an overview of the types of tasks and dialogue that occurred within each lesson. Lab groups varied in size from lesson to lesson, comprising two or more people. Only the lab partners with whom Emily had the most communications and interactions are noted in the following tables and excerpts.
Lesson 1 Analysis: Flame Test (N-Video)

Table 9-2: Lesson 1 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:16.2 - 0:22.4</td>
<td>Tries to turn Bunsen burner knob</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>0:37.0 - 0:47.7</td>
<td>Turns knob</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>9:38.3 - 9:47.1</td>
<td>Records data on BrailleNote</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>10:28.7 - 10:30.7</td>
<td>Dips Q-tip in methanol</td>
<td>N</td>
<td>4</td>
</tr>
<tr>
<td>10:41.5 - 10:43.5</td>
<td>Dips Q-tip in salt</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>10:53.0 - 11:12.1</td>
<td>Holds Q-tip in flame</td>
<td>N</td>
<td>6</td>
</tr>
<tr>
<td>11:28.5 - 11:48.5</td>
<td>Records data on BrailleNote</td>
<td>N</td>
<td>7</td>
</tr>
<tr>
<td>12:18.7 - 12:24.3</td>
<td>Dips Q-tip in methanol</td>
<td>N</td>
<td>8</td>
</tr>
<tr>
<td>12:38.9 - 12:46.2</td>
<td>Dips Q-tip in salt</td>
<td>N</td>
<td>9</td>
</tr>
<tr>
<td>16:07.5 - 16:09.4</td>
<td>Holds Q-tip in flame</td>
<td>N</td>
<td>10</td>
</tr>
</tbody>
</table>

Task 1

TT Lindsey:  Okay, keep your eyes on the Bunsen burners please. Okay, are you ready? Left hand, turn it hard. Partner, start striking.

TT Lindsey: [Moves Emily’s hand to the knob.]
Emily: [Tries to turn Bunsen burner knob.]
Partner 1: [Using striker.]
TT Lindsey: Here, left. Other way, darling.
TT Lindsey: [Reaches to help turn knob.]

Task 2

TT Lindsey: Hold on, honey. Let me help you. Move your hand.
TT Lindsey: [Turns knob.]
TT Lindsey: Okay, now you can go. Go.
Partner 1: [Uses striker.]
Emily: [Turns knob.]
TT Lindsey: [Helps turn knob.]
**Task 3**

Emily: What was it?
Partner 1: Uh, repeat the last one?
Emily: No, was it red or pink?
Partner 1: It was red.
Emily: All right.
Emily: [Records data on BrailleNote.]

**Tasks 4-6**

TT Lindsey: All right, guys, you know the drill. Uncover the methanol. Dip your Q-tip in. Re-cover the methanol. Then dip it in the salt.
TT Lindsey: Okay, ready? Here’s the methanol. Put your left hand on the container here. There you go, yup. Dip the Q-tip in. You got it. That looks good and wet. Okay. And then when you’re ready, you can put it in the flame. You don’t have to wait for me.
TT Lindsey: [Unscrews methanol cap.]
TT Lindsey: [Moves Emily’s left hand to the container.]
Emily: [Dips Q-tip in methanol.]
TT Lindsey: [Unscrews lid on salt.]
TT Lindsey: And then dip it in the salt. There you go. Yeah, you got a ton. Okay, and then we’re going to bring you over to the burner. Okay, and that flame is right there.
Emily: [Dips Q-tip in salt.]
Emily: [Holds Q-tip in flame.]
Partner 1: Whoa! It’s like, it’s like a very pretty red pink. It’s like magenta.
TT Lindsey: Hold it in there for a little bit. You got a lot of salt on there.
TT Lindsey: Okay, you can ...
Partner 1: It’s like the color spectrum.
TT Lindsey: Okay, now we’re good. If you want to just set it down there.

**Task 7**

Emily: I can’t tell at all.
Partner 1: The salt was LiCl. The color was bright pink.
Emily: [Enters information on BrailleNote.]
Partner 1: I’m right here.
Partner 1: You want to do the next one?
Emily: Sure.

**Tasks 8-9**

Partner 1: [Opens methanol.]
Partner 1: And here’s the Q-tip.
Partner 1: No, the other side.
Emily: [Dips Q-tip in methanol.]
Partner 1: Yeah, that’s wet enough.
Partner 1: [Closes methanol.]
Partner 1: [Opens salt.]
Partner 1: Here’s the salt.
Partner 1: You can just dip it in there.
Emily: [Dips Q-tip in salt.]
Partner 1: [Closes salt.]

Task 10

Partner 1: Do you want to stick it in the fire?
Partner 1: I already have it on the Q-tip.
Emily: Sure.
Emily: [Holds Q-tip in flame.]

Investigator Commentary: Due to a greater than normal risk of injury because of the use of the Bunsen burner, TT Lindsey paid close attention to Emily working with the flame. When the flame was in use, Emily’s actions were highly monitored, which limited her independence. However, this monitoring also ensured Emily’s participation. Without the encouragement of TT Lindsey and the lab partner, it is very likely Emily would not have participated nearly as much as she did. TT Lindsey’s being actively engaged in Emily’s lab group probably affected the study’s data regarding this lesson, in that few of the numerous actions recorded for Emily in the transcript would have occurred without Emily having been acted upon by TT Lindsey and the lab partner. TT Lindsey strongly encouraged Emily’s involvement at a higher level than otherwise would have been observed. Emily did function partially independently when it came to recording observations, as the use of her BrailleNote was very familiar to her.
Lesson 2 Analysis: Solubility and Precipitation (N-Video)

Table 9-3: Lesson 2 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:25.4 - 5:30.1</td>
<td>Feels plastic well plate</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>6:29.1 - 7:08.4</td>
<td>Types on BrailleNote</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>8:00.2 - 8:32.8</td>
<td>Types chemical formulas on BrailleNote</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>9:23.4 - 9:29.8</td>
<td>Types chemical equations on BrailleNote with help of aide</td>
<td>N</td>
<td>4</td>
</tr>
<tr>
<td>9:55.8 - 9:58.4</td>
<td>Types on BrailleNote</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>10:02.7 - 10:04.7</td>
<td>Types on BrailleNote</td>
<td>N</td>
<td>6</td>
</tr>
<tr>
<td>10:07.1 - 10:10.9</td>
<td>Types on BrailleNote</td>
<td>N</td>
<td>7</td>
</tr>
<tr>
<td>10:29.9 - 10:34.1</td>
<td>Types on BrailleNote</td>
<td>N</td>
<td>8</td>
</tr>
<tr>
<td>10:34.5 - 10:38.3</td>
<td>Types on BrailleNote</td>
<td>N</td>
<td>9</td>
</tr>
<tr>
<td>10:42.5 - 10:47.7</td>
<td>Types on BrailleNote</td>
<td>N</td>
<td>10</td>
</tr>
<tr>
<td>12:32.4 - 14:17.1</td>
<td>Continues to type chemical formulas on BrailleNote</td>
<td>N</td>
<td>11</td>
</tr>
<tr>
<td>28:52.8 - 29:26.5</td>
<td>Packing up and waiting to wash hands</td>
<td>N</td>
<td>12</td>
</tr>
</tbody>
</table>

Task 1

T Aide: [Tries to hand wells to Emily.]
TT Lindsey: I would not have her touch things. It’s had chemicals in it.
TT Lindsey: I don’t have an extra one, but Emily, basically what it is, just so you know, is it’s like a plastic plate, like you can touch the bottom if you want, but you can’t put your hand in there. But it’s a plastic plate with, can you feel the curves on the bottom? It’s because it’s indented.
Emily: [Feels plastic well plate.]
Emily: Yeah.
TT Lindsey: There are 12 of them. So like three rows.
**Task 2**

Partner 2: From across, there’s like a top. Across first it’s AgNO3. Big A, lowercase g. Then capital N, capital O, and then sub 3. And then it’s, then there’s like, then there’s the next column. It’s kind of confusing. And then it’s big N, little a, N, capital N, capital O, sub 3.

Emily: [Types on BrailleNote.] So AgNO3 is the first one? And then ...

**Task 3**

TT Lindsey: Iron chloride is gonna go in the second row in all four across. So you’re gonna put one drop in each of these four in the second row. Okay? That’s what you’re doing, so do that and pass it on.

Partner 2: Do you wanna do that?

Partner 1: Sure.

Emily: [Types chemical formulas on BrailleNote.]

**Tasks 4-10**

TT Lindsey: Can I make a suggestion? I don’t know, like, Emily, it’s not going to be easy for you to fill it in as a table?

Emily: No.

TT Lindsey: No, so that’s not a practical way for you to do it then. Probably a better way for you to do this would be like ... SO4 plus AgNO3. And then CuSO4 plus NaNO3, do you know what I mean? Cause you’re not gonna be able to set it up in your thing as a table.

Emily: So is that going down and then across?

TT Lindsey: What you can do, is you can do, just write all of them going down, but just write it in the same order, like that we’re gonna do it. So what you could do now is do like CuSO4 plus AgNO3. And what I can do to make things easier is why don’t I number these for you.

Emily: [Types chemical equations in BrailleNote with help of teaching aide.] I can just ...

TT Lindsey: I know, but I’m just saying. I’ll number them so that you know which order to read them in.

T Aide: Oh, okay.

TT Lindsey: And then cause actually we’ll do the reactions this way. And that way she’ll have them in the right order, so then you can fill out what it is. Does that make sense?

T Aide: Are you ready?

Emily: Um, sure.

T Aide: Do you want to start over?

Emily: Yeah.

T Aide: CuSO4 plus.

Emily: Plus.
T Aide: AgNO3.
Emily: [Types on BrailleNote.]
T Aide: And the next one is NaCl3.
Emily: [Types on BrailleNote.]
T Aide: Plus HeNO3.
Emily: [Types on BrailleNote.]
T Aide: The next one is CuSO4 plus NaNO3.
Emily: [Types on BrailleNote.]
Emily: FeCl3.
Emily: [Types on BrailleNote.]
TT Lindsey: FeCl3 is going around, yeah?
T Aide: Plus NaNO4, 3.
Emily: [Types on BrailleNote.]
T Aide: K2PO3.
Emily: K2 what?
T Aide: PO3.
Emily: K2Cl3.
T Aide: Plus NaNO3.
Partner 2: The yellow one was FeCl2.
T Aide: FeCl2.

Task 11

TT Lindsey: You’re not gonna react it with itself.
Partner 1: That’s why you don’t put any in there, because it’s not going to react. So the first three wells of that third row only.
Partner 2: [Fills three wells with potassium carbonate.]
Emily: Cl or ...
Emily: [Continues to type chemical formulas on BrailleNote.]
T Aide: Na3PO4.

Task 12

Partner 2: Okay, we’re done.
Partner 2: [Packing up and waiting to wash hands.]
Emily: [Packing up and waiting to wash hands.]
Partner 1: [Packing up and waiting to wash hands.]

Investigator Commentary: In this lesson, Emily was limited in what she could touch by TT Lindsey. Emily was able to handle the plastic well plate on the bottom side, but TT Lindsey would not let her thoroughly examine a clean well plate for purposes of orientation. Much of the time, Emily was recording data. How she organized her notes
was discussed by TT Lindsey. The teacher’s aide read chemical formulas to Emily to record in her BrailleNote. Emily may have exhibited some frustration with her limited role during this lesson. The use of the well plate also limited Emily’s involvement since the students were using only drop amounts of chemicals. The microscale nature of this procedure prevented Emily from having many hands-on opportunities.
Lesson 3 Analysis: Hydrate (I-Video)

Table 9-4: Lesson 3 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>2:46.1 - 2:49.7</td>
<td>Twists gas jet</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>6:33.7 - 6:44.5</td>
<td>Watching Lindsey demonstrate lighting the burner</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>11:59.9 - 12:04.2</td>
<td>Feels tongs in hand</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>12:19.8 - 12:29.9</td>
<td>Holds crucible with tongs</td>
<td>N</td>
<td>4</td>
</tr>
<tr>
<td>14:36.4 - 14:40.3</td>
<td>Touches gas nozzle</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>15:08.9 - 15:10.7</td>
<td>Turns on gas</td>
<td>N</td>
<td>6</td>
</tr>
<tr>
<td>17:24.8 - 18:44.6</td>
<td>Setting up Logger Pro and troubleshooting computer</td>
<td>I</td>
<td>7</td>
</tr>
<tr>
<td>23:51.2 - 24:17.9</td>
<td>Waiting for crucible to cool</td>
<td>N</td>
<td>8</td>
</tr>
<tr>
<td>27:24.9 - 27:52.6</td>
<td>Weighing crucible</td>
<td>I</td>
<td>9</td>
</tr>
<tr>
<td>28:16.5 - 28:22.9</td>
<td>Recording data in BrailleNote</td>
<td>N</td>
<td>10</td>
</tr>
<tr>
<td>33:46.6 - 34:00.5</td>
<td>Turns on gas jet</td>
<td>N</td>
<td>11</td>
</tr>
<tr>
<td>43:51.9 - 47:41.8</td>
<td>Heating crucible</td>
<td>N</td>
<td>12</td>
</tr>
</tbody>
</table>

Task 1

TT Lindsey:   Okay, first of all, you got the burner itself. Play with that. If you untwist it, you’re going to start to see a gap between them, so you gotta twist, and you should see a gap. If you twist all the way, it’ll twist right off. All right? So don’t do that. Um, that gap right there, listen up, that gap right there is air flow. If you see a big gap, you’ve got way too much air. So what I always do, just to tell you, is I twist it enough so that I see a tiny little gap where maybe I could stick just a little part of my fingernail in there, you know what I mean? So it’s not super big, it’s just enough that you can kind of see that if you twist it a little more you’d make a bigger space.

Emily: [Twists gas jet.]

T Aide: [Twists gas jet.]

T Aide: Twist it like that.
Partner 1: [Twists gas jet.]

TT Lindsey: Okay, this is how I always start out. Now listen, as far as airflow goes, when you turn it on, and you hear “schooo” that means there’s too much airflow and you’re not gonna get a flame because it’s gonna extinguish it as soon as, because there’s too much air.

Task 2

TT Lindsey: And I’ll light it, and we’ll just see how it goes. And I can tell you, first of all, this burner’s dirty, so chances are it’s gonna burn off some gunk, no big deal, it’ll just burn off. It’ll be fine.

TT Lindsey: Okay, so, and I don’t really like doing it this way, but ready? There we go. Okay.

Emily: [Watching Lindsey demonstrate lighting the burner.]

Partner 1: [Watching Lindsey demonstrate lighting the burner.]

T Aide: [Watching Lindsey demonstrate lighting the burner.]

T Aide: The flame is probably about 18 inches up from the top of the burner.

Tasks 3-4

T Aide: Why don’t you let Emily try picking that up with the tongs. Let her check out the tongs and stuff?

Partner 1: Here’s the crucible.

Partner 1: And here’s the tongs.

Emily: [Feels tongs in hand.] Right.

T Aide: Okay, so the crucible goes in the middle here.

T Aide: Those are the hips.

T Aide: So you can see that if you squeeze it too tight, it just cups right out.

Emily: [Holds crucible with tongs.]

Partner 1: [Puts crucible in iron ring.]

T Aide: She has put it in the ring, that’s okay.

Partner 1: [Takes crucible off.]

T Aide: So your ring is right here, so that’s how high your flame is gonna be.

Tasks 5-6

TT Lindsey: All right, girls. You ready?

TT Lindsey: All right, who’s gonna do what?

TT Lindsey: Are you gonna shut on the gas or be the striker, Emily?

Emily: Gas.

TT Lindsey: All right, so you need to switch spots then. Here is your striker, give me a second.

TT Lindsey: So, left hand. Remember I said you pretty much have to lean across the table? Do you feel that nozzle right there?

Emily: [Touches gas nozzle.]
Emily: Yeah.

TT Lindsey: You want that to be in alignment with that.

TT Lindsey: You just turn it when I tell you, all right?

TT Lindsey: [Demonstrating how to use the striker.]

TT Lindsey: Now..., no, don’t do it yet. Now, down at the bottom, you’ll get a better strike if you do it down there, instead of like there, okay?

TT Lindsey: All right, turn it on.

TT Lindsey: Stop.

Emily: [Turns on gas.]

Partner 1: [Uses striker to light Bunsen burner.]

Task 7

TT Lindsey: All right, so you guys, you’re timing. You can go back now, Emily. Are you trying to get that to work?

Emily: Yeah.

TT Lindsey: What happened?

Emily: I don’t know. It just ...

TT Lindsey: Did it go to sleep?

Emily: Yeah.

Emily: It turned on.

TT Lindsey: Can I just do a couple things real quick?

Emily: [Setting up Logger Pro and troubleshooting computer.]

TT Lindsey: You have a message we need to get rid of.

TT Lindsey: Okay, so you have Kurzweil and JAWS opened. What do you want?

Emily: Just close Kurzweil.

TT Lindsey: Close Kurzweil. That’s what you’re in right now.

Task 8

Emily: [Waiting for crucible to cool.]

Partner 1: [Waiting for crucible to cool.]

TT Lindsey: So hopefully your practice with the hips was good.

Emily: Wait, so when do we weigh, or what do we weigh?

Partner 1: Um, we weigh the crucible and then record the weight, and then we put a gram of ... in, and it has to be one more gram than the weight of the crucible.

Task 9

Partner 1: [Transfers crucible from ring to Scout Pro balance.]

Partner 1: Should we go now?

Emily: [Weighing crucible.]

Partner 1: [Weighing crucible.]
Partner 1: Okay, it says 11.3 grams.
T Aide: No, 11.03.

Task 10

Emily: [Recording data in BrailleNote.]
Partner 1: [Takes crucible to lab balance.]
TT Lindsey: It should’ve been around 10 grams, was it?
Emily: Uh, kind of.
Emily: Around.
TT Lindsey: Emily?
Emily: It was like 11.
TT Lindsey: Oh, good, at least it wasn’t 30 or something.

Task 11

TT Lindsey: Get over here. You’re gonna turn on the gas jet.
TT Lindsey: All right, now don’t be shy.
Partner 1: [ Strikes to start flame. ]
Emily: [ Turns on gas jet. ]
TT Lindsey: Good.

Task 12

Emily: [Heating crucible.]
Partner 1: [Heating crucible.]
Partner 1: Just one more minute.

Investigator Commentary: Emily used the ILAB balance to record mass measurements and performed other tasks such as turning the knob to control gas flow and recording observations on her BrailleNote. Handling the tongs and feeling the crucible were also permitted. TT Lindsey encouraged Emily to control the gas flow when lighting the Bunsen burner. Otherwise, Emily preferred to record observations on her BrailleNote; this is the task with which she felt most comfortable since she was very familiar with its functionality. Emily exhibited a lack of understanding of how to use Logger Pro. TT Lindsey intervened and was able to get the software to open. This allowed Emily to take some mass measurements.
Lesson 4 Analysis: Specific Heat (I-Video)

Table 9-5: Lesson 4 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:28.6 - 8:54.2</td>
<td>Pouring liquid into beaker</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>13:43.1 - 13:50.7</td>
<td>Checks length of thermometer cord</td>
<td>I</td>
<td>2</td>
</tr>
<tr>
<td>14:14.2 - 14:17.4</td>
<td>Puts temperature probe in cup</td>
<td>I</td>
<td>3</td>
</tr>
<tr>
<td>14:17.6 - 15:23.9</td>
<td>Works with data on computer</td>
<td>I</td>
<td>4</td>
</tr>
<tr>
<td>17:27.8 - 17:33.2</td>
<td>Sticks temperature probe in water</td>
<td>I</td>
<td>5</td>
</tr>
<tr>
<td>17:42.4 - 17:49.0</td>
<td>Works with data on computer</td>
<td>I</td>
<td>6</td>
</tr>
<tr>
<td>27:04.4 - 27:06.6</td>
<td>Works on computer</td>
<td>I</td>
<td>7</td>
</tr>
<tr>
<td>27:28.0 - 27:29.8</td>
<td>Checks temperature</td>
<td>I</td>
<td>8</td>
</tr>
<tr>
<td>27:45.3 - 27:46.7</td>
<td>Checks temperature</td>
<td>I</td>
<td>9</td>
</tr>
<tr>
<td>33:17.4 - 33:20.5</td>
<td>Zeroes balance</td>
<td>I</td>
<td>10</td>
</tr>
<tr>
<td>34:05.7 - 35:17.6</td>
<td>Troubleshoots computer</td>
<td>N</td>
<td>11</td>
</tr>
<tr>
<td>35:17.8 - 35:21.5</td>
<td>Works with data</td>
<td>I</td>
<td>12</td>
</tr>
<tr>
<td>35:38.4 - 35:39.9</td>
<td>Puts beaker on balance</td>
<td>I</td>
<td>13</td>
</tr>
<tr>
<td>36:06.2 - 36:07.6</td>
<td>Works on computer</td>
<td>I</td>
<td>14</td>
</tr>
<tr>
<td>36:18.0 - 36:43.6</td>
<td>Doing calculations</td>
<td>N</td>
<td>15</td>
</tr>
<tr>
<td>44:24.9 - 44:29.0</td>
<td>Puts probe in water</td>
<td>I</td>
<td>16</td>
</tr>
<tr>
<td>44:37.1 - 44:41.0</td>
<td>Checks temperature</td>
<td>I</td>
<td>17</td>
</tr>
<tr>
<td>44:48.0 - 44:50.0</td>
<td>Checks temperature</td>
<td>I</td>
<td>18</td>
</tr>
<tr>
<td>53:13.8 - 53:15.3</td>
<td>Checks temperature</td>
<td>I</td>
<td>19</td>
</tr>
<tr>
<td>53:16.4 - 53:51.2</td>
<td>Works on computer</td>
<td>I</td>
<td>20</td>
</tr>
<tr>
<td>53:58.9 - 54:03.3</td>
<td>Makes notes</td>
<td>N</td>
<td>21</td>
</tr>
</tbody>
</table>
**Task 1**

Partner 1: There’s a beaker and a Styrofoam cup. Do you pour with your left or right hand?
Emily: Uh, left.
Partner 1: So then we’re gonna pour into the Styrofoam this cylinder and so the top of the cylinder is right above this plastic thing.
Emily: [Pouring liquid into beaker.]
Partner 1: So just tip in slowly and it should go in.
Partner 1: A little faster than that, keep going. Now a little faster. Keep going. You’re gonna pour all the liquid in there.

**Task 2**

Partner 1: Do you think that means we wait for the Styrofoam cup till the 10 minutes are up or ...?
Emily: I don’t know.
Partner 1: Should we just do it now?
Emily: I don’t know.
Partner 1: Because I don’t think the temperature of the Styrofoam cup is going to change in 10 minutes.
Emily: No.
Partner 1: When Emily measures the temperature, should I move this over there or ...?
T Aide: Um, we’ll see how long it can reach.
Partner 1: Grab the thermometer and see how long it is.
Emily: [Checks length of thermometer cord.]

**Tasks 3-4**

Emily: [Puts temperature probe in cup.]
Partner 1: Right there. There you go.
Emily: [Works with data on computer.]
Partner 1: That keeps making noise. Like I think it’s slowly moving.
TT Lindsey: What?
Partner 1: It’s not making noise now, but it’ll like ...
Partner 1: I don’t know.
Partner 1: Do you know the temperature yet?
JAWS: Temperature equals 21.8º C.

**Tasks 5-6**

Emily: [Sticks temperature probe in water.]
Partner 1: [Helps Emily stick temperature probe in water.]
Partner 1: There you go, and now you can let go.
Partner 1: There you go. Now you can sit back down.
Emily: [Works with data on computer.]
Partner 1: [Adjusts temperature probe.]
Partner 1: What was it?
Emily: 97.7.

Tasks 7-9

Partner 1: So, do you want to measure the temperature?
T Aide: All right, Emily.
Emily: [Works on computer.]
Emily: So do I just keep ...?
Partner 1: It’s not going up.
T Aide: At all?
Emily: [Checks temperature.]
Partner 1: [Stirs.]
Partner 1: [Turns off hotplate.]
Emily: [Checks temperature.]

Task 10

Partner 1: [Comes back with unknown.]
Partner 1: All right, Emily, here is unknown substance in a beaker. Right here. It’s heavy, kind of. All right, and then here. First, you’re going to want to re-zero it, which is over here, so push in that.
Emily: [Zeroes balance.]
Partner 1: Um, try it again.
Emily: [Zeroes balance.]
Partner 1: There you go. Now put it right on there. There you go. Just right on there. Then we’ll ... and then can you check it on your computer?

Tasks 11-12

TT Lindsey: Come here, you got to, uh, get him. Go up to, uh, insert.
TT Lindsey: [Troubleshooting computer.]
Emily: [Troubleshooting computer.]
Emily: Insert?
TT Lindsey: What?
TT Lindsey: On your file menu.
TT Lindsey: Do you know where insert is? Like file, edit, experiment. You know what I’m talking about?
Emily: No.
TT Lindsey: Up at the top. Your toolbar. File, edit, experiment.
Emily: Can’t you go here?
TT Lindsey: Go all the way up. See, there’s, that’s edit. And that’s experiment. That’s data. That’s analyze. That’s insert.
TT Lindsey: But we want data?
TT Lindsey: Experiment. Enact interface.
TT Lindsey: There. 72.19.
Emily: [Works with data.]

Tasks 13-15

Partner 1: All right, Emily, so now here’s the beaker. We’re supposed to measure the beaker too, so if you want to set it on there because then you subtract to see how heavy this is.
Emily: [Puts beaker on balance.]
TT Lindsey: Listen up. You do not want to have more than 30 mL of water in that little beaker or it’s gonna overflow and splash everywhere when you put the unknown in and it starts boiling. So if you have too much, you might want to pour some off real quick.
Partner 1: All right, what does it say?
Emily: [Works on computer.]
Partner 1: 28.9.
Emily: So you subtract.
Partner 1: Yup.
Partner 1: So what was the first one? It was ...
Emily: 72.2.
Partner 1: 72.2.
Emily: [Doing calculations.]
Partner 1: [Doing calculations.]

Tasks 16-18

Partner 1: All right, do you want to, um, so we can, do you want to stand up and then come over and, you’re gonna hit the chair, and then you can stop again. Right, like a few more inches, that’s fine. Here is the thermometer. And if you want to, it’s right in there. There you go. All right, so if you want to go back to your seat and then check it.
Emily: [Puts probe in water.]
Partner 1: Should we wait 10 minutes for this one?
Emily: [Checks temperature.]
Partner 1: Did you get it?
Emily: Yeah.
Partner 1: You want to check if it’s going up again?
Emily: [Checks temperature.]

Tasks 19-21

Emily: [Checks temperature.]
Emily: [Works on computer.]
Partner 1: Oh, it’s going up still.
Partner 1: No, it’s going down. Do you want to check it?
Partner 1: 23.7. Um, the highest that I got was 24.5.
Emily: Okay.
Partner 1: So that’s ...
Emily: [Makes notes.]
Partner 1: [Makes notes.]

**Investigator Commentary:** TT Lindsey spent some time assisting Emily in accessing the toolbar on her computer screen. Once Emily was able to access her pull-down menu, she could examine her data points for analysis. She used the balance and the temperature probe to make observations, although she was guided through much of this experiment by her lab partner. Emily had a lot of prompting from her partner regarding when and how to use the tools. TT Lindsey also assisted in some aspects, but most of Emily’s involvement was encouraged by her lab partner. This encouragement may have made her feel that she was part of the group, and she did show at least a small amount of initiative. Emily was more involved in the collection of data during this lesson than during previous lessons.
Lesson 5 Analysis: Le Chatelier’s Principle (I-Video)

Table 9-6: Lesson 5 Video Task Analysis

<table>
<thead>
<tr>
<th>Time Stamp (minutes/seconds into video)</th>
<th>Action</th>
<th>N or I Task</th>
<th>Task Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>2:08.2 - 2:36.8</td>
<td>Touches SALS sensor</td>
<td>I</td>
<td>1</td>
</tr>
<tr>
<td>4:39.8 - 5:13.1</td>
<td>Types</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>5:13.1 - 5:29.3</td>
<td>Touches SALS sensor</td>
<td>I</td>
<td>3</td>
</tr>
<tr>
<td>5:35.0 - 5:44.6</td>
<td>Picks up light sensor, holds it for a bit, then sets it back down</td>
<td>I</td>
<td>4</td>
</tr>
<tr>
<td>5:45.7 - 5:50.6</td>
<td>Types</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>5:50.6 - 5:51.8</td>
<td>Picks up SALS sensor</td>
<td>I</td>
<td>6</td>
</tr>
<tr>
<td>6:12.0 - 6:20.4</td>
<td>Reaches toward test tube with light sensor</td>
<td>I</td>
<td>7</td>
</tr>
<tr>
<td>6:25.5 - 6:46.9</td>
<td>Feels for test tubes, places light sensor into test tube A and holds in place, presses buttons on SALS</td>
<td>I</td>
<td>8</td>
</tr>
<tr>
<td>8:32.5 - 8:45.1</td>
<td>Places light sensor into second test tube</td>
<td>I</td>
<td>9</td>
</tr>
<tr>
<td>8:49.8 - 8:51.0</td>
<td>Points to light sensor</td>
<td>I</td>
<td>10</td>
</tr>
<tr>
<td>8:53.0 - 9:14.0</td>
<td>Presses buttons on SALS sensor</td>
<td>I</td>
<td>11</td>
</tr>
<tr>
<td>9:23.7 - 9:36.5</td>
<td>Grabs light sensor, removes it from test tube, wipes it off with tissue, hands tissue to aide</td>
<td>I</td>
<td>12</td>
</tr>
<tr>
<td>9:41.8 - 10:03.0</td>
<td>Places light sensor into test tube three, presses buttons on SALS</td>
<td>I</td>
<td>13</td>
</tr>
</tbody>
</table>

Task 1

Emily: Did he show you how to use this?
Emily: [Touches SALS sensor.]
T Aide: He just showed it to me. He didn’t really tell me how to use it, though.
T Aide: [Bends down to look at SALS sensor.]
Emily: Oh.
T Aide: All I know is the top one. I just know what the buttons say. That’s all I can tell you.
Emily: Ahh.
T Aide: The top one is power.
Emily: I just can’t remember if you push play and then start, or if you press play and then like, or like start? I don’t get how you’re supposed to push the memory thing. I don’t know, whatever.

Partner 2: [Straightens notebook up on table. Writes in notebook.]

TT Lindsey: How’s it going? Emily, are you about done?

Emily: Yes.

TT Lindsey: So SALS is on and ready to go?

Emily: Not yet.

TT Lindsey: Do you have any questions, or do you know what you’re doing?

Emily: Well, I have to store some, right? [Inaudible.]

TT Lindsey: Yes, do you have your procedure out?

Emily: Yes.

TT Lindsey: Where is it? Because isn’t it all explained in there?

Emily: Not really. It just says use [inaudible].

TT Lindsey: So because there’s how many different storage locations, you could press different combinations of buttons, can’t you?

Partner 1: [Walks onscreen holding a glass beaker containing a tan liquid. Sits down at table next to Emily. Sets down beaker and reads from notebook.]

Emily: Yes, but like I don’t get how you’re supposed to press play and memory and stuff.

Partner 1: So fill them all three quarters full with [inaudible].

Partner 1: [Pulls test tube rack towards self. Picks up glass beaker containing tan liquid.]

Emily: It just says to start them. It doesn’t tell you how.

Partner 1: [Pours tan liquid from glass beaker into all of the test tubes.]

TT Lindsey: What does it say in the procedure?

Emily: It didn’t say anything, because it’s not ...

TT Lindsey: I felt like in the freezing-point one it said something.

Emily: Wasn’t that the dual tone one? I think that was the dual tone one.

TT Lindsey: Yes, well, I don’t know. But wouldn’t you store it the same way?

Emily: Yes, but I don’t know.

Tasks 2-8

TT Lindsey: So do you still have those?

Emily: [Types.]

Emily: [Touches SALS sensor.]

T Aide: Do we need to do a test on the A? The control one?

Emily: Yes, I think so.

Emily: [Picks up light sensor, holds it for a bit, then sets it back down.]

T Aide: So which one’s going to be A?

Partner 1: Um, this one is. Well, okay, I’m going to put this big fat-lipped guy over here, because that can distinguish that this is A. Or whatever you call it, big rimmed. Yes, so that’s like the control.

Partner 1: [Picks up first and third test tubes and switches their placements in test tube holder.]
Emily: [Types.]
Emily: [Picks up SALS sensor.]
T Aide: [Pulls test tube rack closer to Emily’s right-hand side.]
T Aide: So it’s on your right hand.
Emily: [Reaches toward test tube with light sensor.]
T Aide: The big fat-lipped one there.
Partner 1: Yes, right there. You’ve got a bigger thing on top.
T Aide: Yes, that’s the one.
Classmate: [Sets down clear glass dropper bottle with tan liquid onto table.]
Emily: [Feels for test tubes. Places light sensor into test tube A and holds it in place. Presses buttons on SALS sensor.]

**Tasks 9-12**

Emily: [Places light sensor into second test tube.]
Emily: Can you hold this?
T Aide: What?
Emily: Can you hold this?
T Aide: Hold what?
Emily: This.
Emily: [Points to light sensor.]
T Aide: Oh, sure.
T Aide: [Grabs light sensor and holds it straight, keeping it inside test tube. Hands a tissue to Emily.]
Emily: [Presses buttons on SALS sensor.]
Emily: Okay.
T Aide: Okay, do you want to take it out? And here’s your tissue. I’m still holding it.
Emily: [Grabs light sensor, removes it from test tube, wipes it off with tissue. Hands tissue to aide.]

**Task 13**

Partner 1: [Guides Emily’s hand (which is holding the light sensor) to test tube three.]
Emily: [Places light sensor into test tube three. Presses buttons on light sensor.]
Partner 1: That one didn’t even change color. I can hold this.
Partner 1: [Holds light sensor, keeping it inside test tube three.]

**Investigator Commentary:** Emily was allowed to use the SALS to detect the formation of precipitates, but demonstrated a lack of understanding of how the device was to be operated. TT Lindsey tried assisting Emily with the SALS. TT Lindsey asked Emily if
her lab procedure contained instructions on how to use the SALS to record observations. Emily indicated that it did not. TT Lindsey expressed some frustration with Emily, and with having to take the time to help Emily operate the SALS. Anything new with regard to ILAB tools was troublesome for Emily because of her lack of familiarity and practice. She was finally able to use the SALS to make some qualitative observations, which enabled her to be partially involved in the physical tasks of the lab.
Graphic Analysis of Video Data

The data illustrated in Figures 9-1 and 9-2 show the percent of time engaged (PTE) for the BLV student and her sighted lab group partners in performing laboratory-goal-directed actions during laboratory lessons, as described in Chapter 4. For lessons involving more than one sighted partner, the separate PTEs for the partners were combined. To help in understanding the graphical data, instances of multiple partners are noted in the text describing the PTE results for the individual lessons. Sighted students may have rotated from lab to lab. Emily is indicated in blue, and the sighted partners are indicated in red. Figure 9-1 shows the results of the two lessons conducted without the use of ILAB tools, and Figure 9-2 shows the results of the three lessons conducted with ILAB tools.

In Lesson 1, Emily exhibited 43.5% PTE, while the sighted student exhibited 56.5% PTE. In Lesson 2, Emily’s observed PTE was 6.0%, and her two sighted partners contributed 94.0%. Her PTE was relatively high in Lesson 1 primarily because TT Lindsey provided a great deal of hand-on-hand instruction, leading Emily through many of the steps, which raised the BLV student’s participation. This hand-on-hand involvement may have occurred because of Emily fearing to work with an open flame or because the teacher felt the exercise presented a large safety risk.

With ILAB tools, Emily’s PTEs were 22.7%, 58.8%, and 51.3% in Lessons 3-5, respectively. She had two partners in Lesson 5, but the second partner contributed very little PTE to the total. Her overall performance was substantially higher in the lessons incorporating ILAB tools as compared to the lessons not incorporating ILAB tools.
Emily’s apparent high PTEs for Lessons 4 and 5, however, may be at least partially misleading. She participated in tasks only when directly prompted to do so by TT Lindsey and/or her partners. She required explicit prompting for most aspects of the labs, taking little action on her own initiative. Emily’s involvement in her lab groups was largely dependent upon her partners and their levels of interest in incorporating her into the lab activities. When close guidance was not provided and the partners did not strive to involve Emily with the lab tasks, she fell back into her comfort zone of letting others perform experiments for her. However, when her partners or TT Lindsey encouraged her to participate by instructing her to manipulate lab materials and equipment, including ILAB tools, Emily was willing to comply.

The ILAB tools may have improved Emily’s PTE by making increased hands-on laboratory participation possible for her, but she likely would have seldom used the tools without direct prompting from the teacher or lab partners.
Figure 9-1: Percent of Time Engaged During N-Video Lab Sessions for BLV Student and Sighted Partner

Figure 9-2: Percent of Time Engaged During I-Video Lab Sessions for BLV Student and Sighted Partner
Video Analysis Rubric Results

Table 9-7 shows the results of the ILAB video analysis rubric, which was designed to collect information regarding the levels of acceptance of the BLV students into their lab groups. (See the explanation in Chapter 4 and the rubric questionnaire in Table 4-5.) The three raters made numerical rankings of each of the eight rubric items for each of the five videos of Emily included in this study. The lessons conducted without ILAB tools are labeled as “N,” while the lessons conducted with ILAB tools are labeled as “I.” The three raters are identified as “EE” for the external evaluator, “IR” for the independent rater, and “IS” for the investigator in this study. For the yes/no items (A, B, E), “yes” is coded as 1 and “no” is coded as 0. For the Likert-scale items (C1-C4 and D), “strongly agree” is 5, “no opinion” is 3, and “strongly disagree” is 1.

Table 9-7: Video Analysis Rubric Results

<table>
<thead>
<tr>
<th>Rubric Item</th>
<th>Lesson 1 (N)</th>
<th>Lesson 2 (N)</th>
<th>Lesson 3 (I)</th>
<th>Lesson 4 (I)</th>
<th>Lesson 5 (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EE</td>
<td>IR</td>
<td>IS</td>
<td>EE</td>
<td>IR</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>C1</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>C2</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>C3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>C4</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 9-8 summarizes the patterns seen in Table 9-7, indicating the total number of occurrences found for each of the numerical rubric rankings and the averaged N vs. I scores for each rubric item. Substantial variability was observed both for the binary (yes/no) items and the Likert-scale ratings. This is consistent with the inter-rater reliability coefficients discussed in detail in Chapter 10.

Table 9-8: Patterns Observed with the Video Analysis Rubric

<table>
<thead>
<tr>
<th>Rubric Item</th>
<th>Summary of Scores</th>
<th>Average N</th>
<th>Average I</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7 ones of 15 possible</td>
<td>0.33</td>
<td>0.56</td>
</tr>
<tr>
<td>B</td>
<td>10 ones of 15 possible</td>
<td>0.67</td>
<td>0.67</td>
</tr>
<tr>
<td>C1</td>
<td>2 fours, 5 threes, 7 twos, 1 one</td>
<td>2.5</td>
<td>2.6</td>
</tr>
<tr>
<td>C2</td>
<td>1 five, 11 fours, 2 threes, 1 two</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>C3</td>
<td>1 four, 1 three, 11 twos, 2 ones</td>
<td>2.0</td>
<td>2.1</td>
</tr>
<tr>
<td>C4</td>
<td>4 fours, 5 threes, 6 twos</td>
<td>2.8</td>
<td>2.9</td>
</tr>
<tr>
<td>D</td>
<td>1 five, 6 fours, 3 threes, 5 twos</td>
<td>3.0</td>
<td>3.3</td>
</tr>
<tr>
<td>E</td>
<td>9 ones of 15 possible</td>
<td>0.50</td>
<td>0.67</td>
</tr>
</tbody>
</table>

For rubric item A, Emily had little involvement in group discussions related to the completion of the laboratory goal for Lessons 1, 2, and 5, but demonstrated more participation in group discussions during Lessons 3 and 4. There was some inter-rater disagreement in Lessons 1-3, with only the independent rater consistently providing a ranking of 1. Perfect agreement occurred among the raters for Lessons 4 (all ones) and 5 (all zeroes). Emily participated the least in discussions during Lesson 5. When averaged, however, the rankings for item A indicate greater overall involvement in group discussions for the I-lessons as compared to the N-lessons.

For item B, there was complete agreement among the raters for all lessons except Lesson 2 (for which the independent rater alone provided a ranking of 1). Regarding
Lessons 1, 3, and 4, the raters indicated that the sighted students accepted the contributions of the BLV student when she chose to participate, while Lesson 2 exhibited little acceptance and Lesson 5 indicated none, which corresponds with Emily’s lack of participation in discussions as found in item A for Lessons 2 and 5. The averaged rankings show no difference overall when comparing the N-lessons to the I-lessons.

The averaged rater scores for item C1, which asked whether the BLV student expressed high overall interest in the experiments, show little difference overall between the N-lessons and the I-lessons. Rater disagreement of two levels was seen in each of Lessons 1, 2, and 4. This indicates the raters were unclear in their interpretations of the level of interest of the BLV student for these lessons. The hand-on-hand instruction provided by the teacher in Lesson 1 may have led to possible ambiguities among the raters. In Lessons 1 and 2, the investigator provided rankings higher than did the other raters. There was perfect agreement among the raters for Lesson 5, with all providing a ranking of 2. Averaged rater scores indicate that Emily did not show high overall interest in any of the lessons.

Raters’ scores exhibited little difference between the N-lessons and the I-lessons for item C2, which asked if the level of interest of the BLV student remained the same throughout the experiment. Averaged rater scores indicate mild agreement with the statement, with a variation of two levels for Lesson 1, and perfect agreement for Lessons 3 and 4, with all raters providing rankings of 4. Emily exhibited low interest to begin with; the rankings illustrate that access to the ILAB tools did not affect her interest level.

This is also reflected in item C3, which asked if the level of interest of the BLV student increased throughout the experiments. Rater scores indicate solid disagreement
with this statement, with the only exceptions being a single ranking of 4 in Lesson 4 and a single ranking of 3 in Lesson 1, both provided by the investigator in this study. Averaged scores exhibit little difference between N-lessons and I-lessons. Little difference between the N-lessons and I-lessons likewise is seen in the averaged rater scores for item C4. These averaged scores indicate that the raters did not observe a decrease in Emily’s level of interest during the lessons. However, there is rater disagreement of two levels in each of Lessons 1, 3, and 4, with rankings ranging from 2 to 4. In Lesson 3, two of the three raters felt that Emily’s level of interest went down. Taken together, the scores for C3 and C4 indicate that Emily’s level of interest neither went up nor down during the lessons but rather stayed the same, as was mildly supported by the scores for item C2.

For item D, rater scores show that Emily’s contributions were perceived by her sighted lab partners as beneficial in Lessons 1, 3, and 4. However, this was not the case in Lessons 2 and 5, for which low rater scores indicate that her contributions were not perceived as beneficial. Averaged rater scores show a small improvement from the N-lessons to the I-lessons.

Regarding item E, complete rater agreement was found in Lessons 1 and 4 that Emily was included in the collaborative participation of the group. The scores for Lesson 2 exhibited complete agreement that she was not included. For Lesson 3, two of the three raters found that Emily was included, and in Lesson 5 only one of the three raters found this to be so. Averaged rater scores show a small improvement in the I-lessons as compared to the N-lessons.
The case of Emily had the most rater disagreement of all the case studies, particularly in Lesson 1. Rater disagreements of only one level within individual Likert-scale rubric items may have been due to small variations in interpretation and/or perception, whereas disagreements of greater than one level may have been at least partially caused by unintentionally ambiguous terminology in the rubric, as discussed in Chapter 10. However, Emily seemed to engender the most variation in interpretation for the raters of her observed responses to prompting from her teacher and lab partners while exhibiting minimal personal initiative.

**Summary**

The higher PTE in Lesson 1 than in Lesson 2 may have been impacted by TT Lindsey’s direct involvement in Emily’s participation. She meant well to involve and protect Emily from injury; however, TT Lindsey’s direct actions with Emily substantially affected the results for this lesson. Likewise, Emily’s relatively high participation in Lessons 4 and 5 was at least partly due to TT Lindsey and the lab partners urging Emily to share in various tasks. This urging pushed Emily to become involved in a range of laboratory activities including handling equipment and chemicals, instead of just being relegated to taking notes; this can be observed both in the Video Task Analysis section and the Graphic Analysis of Video Data section. While Emily was forced to depend more on the tools and less on TT Lindsey in the lessons with ILAB tools, she still required frequent encouragement from the people around her.

Emily’s passive approach to learning led to reduced levels of participation when working with tools and technology she did not feel very familiar with. Emily exhibited a
high level of efficacy with some of the ILAB tools because she was more comfortable with them, but the SALS in Lesson 5 was another matter. She had received training on SALS functionality on two prior occasions, but her transfer of knowledge from those previous experiences to Lesson 5 was only partly successful. Emily spent several minutes during this lesson trying to figure out how to use the SALS while her lab partners continued the experiment without her. This led to a reduced amount of time available for Emily to participate in the lesson; the several minutes spent struggling with the SALS were not included in her PTE. With the help of TT Lindsey, Emily eventually used the SALS to collect several data points, which helped result in a respectable PTE.

Emily (and TT Lindsey) had received ILAB tool training at the beginning of the school year and the middle of the school year. These training sessions included instruction on using the SALS. Additional detailed lab procedures were provided to TT Lindsey, incorporating ILAB tools directly into the experiments, which assisted Emily with her ILAB tool use. Still, Emily indicated the instructions were not detailed enough to assist her in successfully operating the SALS, which caused visible frustration for TT Lindsey. It is likely that if Emily had practiced with the SALS after each training session and prior to classroom use, as she had been instructed to do, she would have had less confusion and more confidence in using the tool.

In lessons for which Emily used the JAWS/Logger Pro interface with a temperature probe and a balance, she exhibited familiarity with the JAWS hotkey strokes needed to obtain real-time probe readings. She was then able to record her data points on her BrailleNote, with which she was very familiar. However, Emily exhibited a lack of familiarity with how her Windows Vista laptop computer functioned. This was
compounded when troubleshooting was necessary to get Logger Pro to work properly. It is possible that other software packages running in the background may have interfered with Logger Pro’s ability to run smoothly.

Had Emily been provided with more detailed ILAB tool training, her feelings toward the hands-on aspects of her chemistry class might have changed for the better. Also, had Emily been more motivated to practice using the ILAB tools outside of class, it would have aided her transfer of knowledge from the training sessions to usage in the lab. TT Lindsey felt it was Emily’s responsibility to learn how to use the tools and that it was up to Emily to determine how best they should be incorporated into the lab curriculum. This belief may have negatively impacted Emily’s ILAB tool experience, as she had no one in the classroom to turn to for help.

Emily never contacted the investigator outside of training modules with inquiries about using the tools. After she learned how to use the JAWS/Logger Pro interface to obtain a real-time reading for a single probe, she exhibited limited efficacy with the technology. Emily’s mother contacted the investigator via telephone about Emily’s success with the probe reading and said that this had made a significant impact on her ability to participate in the lab in a more independent manner. However, Emily never seemed to advance to using multiple probes for an experiment. She did not push herself to practice the more advanced features of the JAWS/Logger Pro interface, thus limiting the types of activities in which she could be directly involved. When an experiment required the use of only one probe, Emily was able to become integrated into the procedures. However, when the experiment involved more than one probe, Emily was not able to fully participate.
Another limitation was that the JAWS/Logger Pro interface with the Vernier probes was not capable of working in a microscale environment. These tools require macroscale quantities of chemicals. Whenever substantial lead time was provided to the investigator, stock solutions and necessary glassware were shipped to TT Lindsey to be used by Emily to substitute for microscale environments.

Emily’s SAI II results and her pre/post-school-year interviews present slightly contrasting data. According to her SAI II results, Emily exhibited very little change in attitude toward science from the pre-school-year survey to the post-school-year survey, with an overall improvement of only 2 points. Conversely, during the pre-school-year interview, Emily expressed guarded optimism toward her upcoming chemistry class but, by the end of the school year, had shifted more toward negativity regarding the lab component of the class. She preferred the textbook concepts. Her lack of understanding of how some of the ILAB tools functioned may have contributed to this preference for textbook instruction.

The Video Analysis Rubric section further revealed low participation in laboratory discussions and lower than average interest in the experiments, although Emily’s partners generally accepted her contributions when she chose to participate. Emily did not often express a willingness to participate in labs unless she was directly prompted by her lab partners to do so, as was clearly seen in the Video Task Analysis section. When her group partners did not provide prompting, Emily’s involvement in lab activities dropped noticeably. However, she was always willing to record observations on her BrailleNote.
Emily has a quiet personality, which was compounded by her soft voice. These characteristics inhibited her ability to contribute to discussions and tasks within her lab groups. Emily also exhibited the traits of a typical teenager, such as focusing on social interactions with her friends more than on her classroom learning interactions. The investigator did not document which of her lab partners were her friends versus which were merely acquaintances; had this aspect been documented, it might have shed additional light on her lab group dynamics.

Overall, the SAI II results and the rubric analysis both indicate a minimal difference in Emily’s participation between the lessons without ILAB tools and the lessons with ILAB tools, while the video task analysis and graphic analysis indicate possible improvements. More training time may have been necessary both for the teacher and the BLV student prior to the school year. Additionally, more feedback from the teacher and the student during the school year regarding the functionality and use of the ILAB tools would have been helpful to the teacher, the student, and the investigator.
Chapter 10

Cross-Case Analysis

In this investigation, four cases were studied to document – both qualitatively and quantitatively – the stories of the participants in year one of the ILAB study involving students in mainstream high schools. The similarities and differences among the cases were observed, as were patterns across the cases. The data includes information on demographics and school resources, the laboratory lessons, student and teacher interviews, participating students’ attitudes toward science as evidenced by their SAI II scores, their usage of ILAB tools during lab sessions as observed in the audiovisual recordings, and their level of acceptance into lab groups as determined via the video analysis rubric. All case studies were constructed in a similar format to aid in comparison.

Comparison of Demographics and School Resources

Basic demographic information was provided by the administration offices of the participating schools and is summarized in Table 10-1. The schools ranged from small to midsize to large in student population. Twin Pines had the smallest population at 200, and Badger had the largest at 3,000. Rollinsville was also large, with a population of 2,000, while Highland Hills was midsized at 1,000. These numbers are rounded approximations.

The wide variations in student population impacted the physical resources available to the teachers in this study. Class size may also have had some impact on the amount of time the teachers were able to spend with each student. For instance, in the case of the smallest school – Twin Pines – TT Lindsey devoted a great deal of attention
to Emily, while much less involvement was seen from the participating teachers in the three larger schools. However, quantified data on the percent of time per lesson that each teacher was actively involved with the participating BLV students was not gathered, due to inconsistencies in the starting and stopping times of the video recordings. That is, some teachers did not turn on the camera until partway into the lessons and, in some instances, the video camera stopped recording prior to the end of lessons.

Table 10-1: Demographic Information for the Four Schools

<table>
<thead>
<tr>
<th>School</th>
<th>Approx. # of Students</th>
<th>% Male Students</th>
<th>% Female Students</th>
<th>% Non-Caucasian Students</th>
<th>% Caucasian Students</th>
<th>% Eligible Reduced-Price/Free Lunch</th>
<th># of Science Faculty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Badger</td>
<td>3,000</td>
<td>53%</td>
<td>47%</td>
<td>18%</td>
<td>82%</td>
<td>27%</td>
<td>9</td>
</tr>
<tr>
<td>Highland Hills</td>
<td>1,000</td>
<td>50%</td>
<td>50%</td>
<td>11%</td>
<td>89%</td>
<td>Not available</td>
<td>15</td>
</tr>
<tr>
<td>Rollinsville</td>
<td>2,000</td>
<td>51%</td>
<td>49%</td>
<td>67%</td>
<td>33%</td>
<td>26%</td>
<td>11</td>
</tr>
<tr>
<td>Twin Pines</td>
<td>200</td>
<td>47%</td>
<td>53%</td>
<td>43%</td>
<td>57%</td>
<td>17%</td>
<td>2</td>
</tr>
</tbody>
</table>

Less teacher interaction led to more BLV student interpretation of how the ILAB tools were to be used in the lessons, but in some cases more supervision by the teacher encouraged the BLV student to use the ILAB tools more, such as with TT Lindsey’s frequent encouragement of Emily.

The size of the science faculty also varied among schools, from a high of 15 to a low of 2. The ratio of student population to number of science teachers per school reveals the most favorable ratio at Highland Hills, at approximately 65 to 1. Next is Twin Pines at approximately 100 to 1, Rollinsville at approximately 180 to 1, and Badger at
approximately 330 to 1. The largest school had the highest number of students per science teacher, while the midsized school had the lowest. This may indicate that Highland Hills valued science education the most of the four schools in this study.

The percentages of boys and girls for the four schools were close to 50% in all cases. Rollinsville had the lowest percentage of Caucasian students and highest percentage of African-American students. Badger and Highland Hills had the highest percentages of Caucasians, both exceeding 80%; these figures may indicate some similarities in social structure between Highland Hills and Badger. Twin Pines had a student population of 57% Caucasian and the most diverse mix of ethnicities.

Demographic composition may have affected the functioning of some lab groups, in that heterogeneity or homogeneity in race, socioeconomic status, and gender may have influenced communications and interactions among lab group members, but such effects were not investigated or controlled for in this study.

No comparisons could be made between the performance of male versus female BLV students in this study due to the small sample size and having only one participating female student.

**Comparison of Laboratory Lessons between Schools**

The following table lists all participants’ pseudonyms, type of course taken, and laboratory lesson titles. A few lessons, while having different titles due to having been pulled from the various lab manuals being used in the classes, were similar in pertinent aspects. The ILAB tools were found to be successfully incorporated into all ILAB-tools lessons listed in Table 10-2.
Table 10-2: Laboratory Lessons for the Four Schools

<table>
<thead>
<tr>
<th>School</th>
<th>Student</th>
<th>Teacher</th>
<th>Course Name</th>
<th>N-Lessons</th>
<th>I-Lessons</th>
</tr>
</thead>
</table>
| Badger            | Nate    | Donald  | Chemistry      | 1. Density of Sugar Solution  
2. Separation of Components of a Mixture | 3. Boiling Point Determination  
4. Solubility of an Unknown  
5. Which Is Your Metal? |
| Highland Hills    | Ryan    | April   | AP Physics     | 1. Balance  
4. Falling Mass Cars  
5. Pendulum |
| Rollinsville      | Neil    | Nancy   | AP Chemistry   | 1. Alum Analysis  
2. Heat of Magnesium | 3. Colligative Properties  
4. Equilibrium  
5. Titration |
| Twin Pines        | Emily   | Lindsey | Chemistry      | 1. Flame Test  
2. Solubility and Precipitation | 3. Hydrate  
4. Specific Heat  
5. Le Chatelier’s Principle |

Three of the four classes were in chemistry, with one of them being an AP course. The physics course at Highland Hills was also AP. The two regular chemistry classes had one lab activity in common as relating to solubility, and one regular chemistry course and the AP chemistry course both had lessons on equilibrium. The rest of the analyzed lessons were all dissimilar from each other in subject matter. All students in this study were college-bound, and all in fact went on to college after graduating from high school, with Neil and Ryan choosing STEM-related majors. While not all the participating students enrolled in science-related college majors, science classes such as those listed above were pre-college academic requirements for some.
Comparison of Student/Teacher Interviews

All the participating BLV students had had previous science courses with laboratory components and experienced frustrations during these earlier courses with their lack of ability to fully participate in the laboratory exercises and become fully integrated into their lab groups. All indicated that the ILAB tools helped them to participate more in the hands-on aspects of laboratory tasks. Nate, Ryan, and Neil all indicated in their pre-year interviews a desire to participate more in labs and, during their post-year interviews, agreed that ILAB tools had increased their overall participation during labs, helped them be more fully integrated and accepted into their lab groups, and increased their interest in studying science. Neil stated that the laboratory sessions were his favorite part of his AP chemistry class. Emily, however, while indicating some optimism toward her class in her pre-year interview, later indicated in her post-year interview that her chemistry class had actually decreased her interest in science.

Neither Nate nor Ryan reported any apprehension toward their upcoming respective science classes during their pre-year interviews, while Emily did indicate some apprehension. Neil did not have a pre-year interview, as explained in Chapter 8. In their post-year interviews, all of the participating BLV students indicated at least some positive effect from their participation in the ILAB project, including Emily, who said the laboratory lessons were “cool” and she had learned that, while science was challenging for her, it was not impossible.

One common theme may have been an increase in enjoyment of science class by being able to directly participate in the hands-on activities. Another theme was the enjoyment of working with others to solve problems, which was specifically mentioned
by Ryan and Neil and implied by Nate. Emily was the most negative of the four participating students, perceiving herself as being very limited in her abilities to participate, although her ILAB experience seemed to have made her at least somewhat more aware of what she could really do. Ryan was the most positive in his post-year comments, stating that his greatest enjoyment came from working with his lab partners on solving challenging scientific problems. He is also the only student to claim that he worked on most aspects of the laboratory tasks rather than sometimes focusing on those with which he felt most familiar and comfortable. Although Nate said he liked to challenge himself and was observed trying many different types of activities, he also indicated that sometimes he preferred to carry out familiar tasks.

Both Nate and Neil had some residual vision and were able to read large print and see some objects, which facilitated their ability to participate in some aspects of the labs, possibly leading to greater involvement in non-ILAB tasks than might have occurred otherwise. However, Nate acknowledged that his visual impairment still made working in laboratories difficult for him, as did Neil, although Nate also said that the biggest laboratory-related challenge for him regarding his impairment was the attitude of his sighted classmates, whom he indicated had needed convincing that he was capable of participating in laboratory activities.

In the post-school-year teacher interviews, all the teachers agreed that student efficacy in using the ILAB tools improved as the school year progressed. They agreed for the most part that the tools were helpful to the BLV students, but the degree of helpfulness was largely dependent on how well the students comprehended their use. HT April, RT Nancy, and TT Lindsey in particular found the tools to be beneficial for the
students, while BT Donald said the ILAB tools were helpful yet had limited capabilities. None of the teachers found the ILAB tools to be a hindrance to hands-on laboratory participation, as long as they functioned properly.

TT Lindsey indicated that Emily’s limited participation in class was highly dependent on the willingness of her partners to prompt her and her willingness to be coaxed. As TT Lindsey said in her interview, “Emily really only gets involved to the extent that her partners push her to get involved.” TT Lindsey said that Emily was certainly capable of participating, especially when it came to collecting data with the use of the ILAB tools, but that she preferred not to. “It wasn’t like she wasn’t able to contribute, but I would say she often chooses to not contribute,” said TT Lindsey. TT Lindsey also indicated that Emily’s interactions with her partners remained much the same throughout the school year, no matter who the partners were.

The teachers for Nate, Ryan, and Neil indicated that these students worked well in groups and experienced an improvement in student interactions as the school year went on. HT April even said that Ryan functioned in his lab group “as well as any member of any other team.... They work very well together, probably better than any of the other teams in the class.” RT Nancy indicated that Neil’s visual impairment did not have much impact on Neil’s participation in the lab: “The impact in the lab as a whole, in all of the labs we did, there was very little.”

**Comparison of SAI II Results**

Table 10-3 illustrates the changes from pre-school-year to post-school-year in attitudes toward science for the four BLV students in this study, as determined by their
SAI II scores. As described in Chapter 4, higher scores indicate more positive attitudes.

The scores reveal small to moderate improvements for all four participants from pre-test to post-test, with Ryan and Neil improving the most.

Table 10-3: Comparison of SAI II Scores

<table>
<thead>
<tr>
<th>Construct</th>
<th>Nate</th>
<th>Ryan</th>
<th>Neil</th>
<th>Emily</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre 1AB</td>
<td>22</td>
<td>23</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>Post 1AB</td>
<td>23</td>
<td>24</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Pre 2AB</td>
<td>23</td>
<td>16</td>
<td>22</td>
<td>21</td>
</tr>
<tr>
<td>Post 2AB</td>
<td>20</td>
<td>25</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td>Pre 3AB</td>
<td>24</td>
<td>30</td>
<td>26</td>
<td>22</td>
</tr>
<tr>
<td>Post 3AB</td>
<td>26</td>
<td>29</td>
<td>26</td>
<td>22</td>
</tr>
<tr>
<td>Pre 4AB</td>
<td>20</td>
<td>16</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>Post 4AB</td>
<td>18</td>
<td>17</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>Pre 5AB</td>
<td>20</td>
<td>28</td>
<td>19</td>
<td>22</td>
</tr>
<tr>
<td>Post 5AB</td>
<td>22</td>
<td>28</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>Pre 6AB</td>
<td>42</td>
<td>43</td>
<td>22</td>
<td>31</td>
</tr>
<tr>
<td>Post 6AB</td>
<td>43</td>
<td>44</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td>Total Pre</td>
<td>151</td>
<td>156</td>
<td>124</td>
<td>137</td>
</tr>
<tr>
<td>Total Post</td>
<td>152</td>
<td>167</td>
<td>139</td>
<td>139</td>
</tr>
<tr>
<td>Total Change Pre/Post</td>
<td>+1</td>
<td>+11</td>
<td>+15</td>
<td>+2</td>
</tr>
</tbody>
</table>

For each of the six constructs in the SAI II, paired sample t-tests were conducted to determine whether the mean subscores for the post-tests were significantly greater than the mean subscores for the pre-tests. The null hypothesis was that the mean subscores for the post-tests would equal the mean subscores for the pre-tests. The alternative hypothesis (if the null hypothesis was rejected) was that the mean subscores for the post-tests would be greater than the mean subscores for the pre-tests. For the four students, the
degrees of freedom (df) were \( n - 1 = 3 \). The overall type I error rate (\( \alpha \)), which is the probability of erroneously finding a significant effect, was controlled to be 0.05 through the use of a Bonferroni correction. IBM’s Statistical Package for the Social Sciences (SPSS) software was used to calculate the t statistic, or \( t^* \), values. The 95th percentile of a t-distribution with 3 df (identified as \( t_{\text{critical}} \)) was then used as comparison for these \( t^* \) values. With the Bonferroni correction, the individual error rate for each of the six t-tests (one for each of the six attitudinal constructs) was \( \alpha = 0.05 \div 6 = 0.00833 \). Next the \( t^* \) values were compared to \( t_{\text{critical}} \), or 4.85666, which was \( (1 - 0.00833) \times 100 = 99.167 \)th percentile of a standard t-distribution with 3 df.

To further verify the t-test results, permutation tests were also used. With the aid of a statistician, this was accomplished by constructing a reference distribution for comparison to the \( t^* \) values. The reference distribution was determined through using all combinations of the complete SAI II data set from the four case studies. The permutation tests confirmed the findings of the t-tests for all six constructs.

For the t-tests, because \( t^* < t_{\text{critical}} \) for all six constructs, the null hypothesis could not be rejected for any of the constructs, indicating that the mean subscale score for each attitudinal construct did not significantly increase from pre-test to post-test. In other words, there was not enough evidence to definitively claim that the mean score for each construct significantly increased. This conclusion was confirmed by the permutation tests, which likewise found that the null hypothesis could not be rejected. The results of the t-tests and permutation tests are shown in Table 10-4.
Table 10-4: Paired Sample T-Tests and Permutation Tests with Bonferroni Correction

<table>
<thead>
<tr>
<th>Attitudinal Construct</th>
<th>T*</th>
<th>$T_{critical}$ (for t-test)</th>
<th>Reject Null Hypothesis? (for t-test)</th>
<th>$T_{critical}$ (for permutation test)</th>
<th>Reject Null Hypothesis? (permutation test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1AB</td>
<td>3.000</td>
<td>6.23242</td>
<td>No</td>
<td>15.00</td>
<td>No</td>
</tr>
<tr>
<td>2AB</td>
<td>0.666</td>
<td>6.23242</td>
<td>No</td>
<td>0.600</td>
<td>No</td>
</tr>
<tr>
<td>3AB</td>
<td>0.397</td>
<td>6.23242</td>
<td>No</td>
<td>11.00</td>
<td>No</td>
</tr>
<tr>
<td>4AB</td>
<td>0.905</td>
<td>6.23242</td>
<td>No</td>
<td>7.000</td>
<td>No</td>
</tr>
<tr>
<td>5AB</td>
<td>0.212</td>
<td>6.23242</td>
<td>No</td>
<td>3.000</td>
<td>No</td>
</tr>
<tr>
<td>6AB</td>
<td>1.571</td>
<td>6.23242</td>
<td>No</td>
<td>7.000</td>
<td>No</td>
</tr>
</tbody>
</table>

Source: Adapted from Johnson and Fu (2010)

However, while the t-test and permutation test results of the group as a whole did not reveal a statistically significant change in SAI II scores from pre-test to post-test, this does not necessarily mean that participation in the ILAB study did not result in personally significant improvements in attitude toward science for the individuals involved. The two lowest pre/post increases in SAI II scores (Nate and Emily) necessarily brought down the mean of the group, flattening the pre-test to post-test increases of Ryan and Neil. The investigator is reminded of the parable of the thousands of starfish washing up on shore and a man throwing them back into the water one by one to save their lives, when another man walks up and declares there are too many starfish for anyone to be able to make a difference (Eiseley, 1979; Barker, 2007). The first man throws yet another starfish back into the sea and pointedly replies, “It made a difference for that one.” Who is to say that the 15-point SAI II increase for Neil and the 11-point increase for Ryan did not make a
personal difference to those two individuals, both of whom went on to choose STEM majors in college? (This is not to claim that the choice of STEM majors by these students was the result of participation in the ILAB study, however, since both were enrolled in AP courses during 2007-08 and thus had a strong preexisting interest in science.)

**Comparison of Video Task Analyses**

The video task analyses revealed that Nate, Ryan, and Neil were generally more involved in the laboratory activities and discussions than was Emily. Nate and Ryan were more obviously verbal than were Neil and Emily, both of whom exhibited quiet personalities. Nate and Ryan were also more independent in their activities, took more initiative in laboratory actions, contributed more to laboratory-goal-directed discussions, and seemed to be highly motivated, although Nate spent a substantial amount of time in recording data for at least one lesson. Emily contributed the least to discussions within her lab groups and exhibited the lowest level of personal initiative. However, Neil and Emily experienced the greatest improvement both in the amount of time involved in laboratory tasks and the range of tasks accomplished during the lessons with ILAB tools as compared to those without ILAB tools, with Neil possibly having benefitted the most.

Ryan’s intellectual contributions to his lab groups were probably the highest, followed by those of Nate. Ryan had the greatest comprehension of the scientific concepts in the laboratory lessons, again followed by Nate. Neil didn’t fully understand everything going on in all the lessons, including the pertinent theories and concepts, which likely negatively impacted his level of involvement. Reduced involvement, in turn, probably impacted his level of understanding. He contributed little intellectually in most
of the lessons, including both N-lessons, but improved notably in Lesson 5. Emily’s intellectual contributions were minimal in all five labs. There is no way to know how much Emily comprehended, but her understanding appeared to be low. She was most comfortable taking notes and didn’t seem to want to become involved in the lab activities. This is in contrast to the other BLV students, who appeared motivated to become involved.

Ryan exhibited the highest overall involvement in the labs and enthusiasm for the activities, both in the N-lessons and the I-lessons, and did well in both kinds of lessons. Nate was also highly involved in the labs and seemed enthusiastic. Nate and Ryan appeared to have the greatest understanding of the ILAB tools, and felt comfortable both with the N-tools and the I-tools. Ryan in particular was not dependent on the ILAB tools. He often chose to let his partners use the I-tools while he used N-tools and equipment, although he demonstrated very clear understanding of ILAB tool functionality. Ryan also had excellent comprehension of how his computer worked, and used his computer rather than a BrailleNote for taking notes. Emily had some trouble with the SALS, as did Neil, and also had difficulty understanding how to use multiple probes during lab sessions. She had the most limited understanding of ILAB tool functionality.

Nate, Ryan, and Neil were more willing to become involved in their lab groups than was Emily. While Neil was very quiet and largely marginalized during the N-lessons, he contributed more to the completion of laboratory goals – both through actions and utterances – during the I-lessons. His partners performed most of the decision-making in all lessons; however, during the I-lessons Neil was more verbal and more incorporated into his lab groups, and his range of hands-on manipulations of chemicals
and equipment was greater. His levels of group incorporation and intellectual involvement did not reach those of Ryan or Nate, but improvement was substantial from the N-lessons to the I-lessons, particularly in Lesson 5.

If Emily had not been repeatedly prompted by her teacher and lab partners to participate, she would likely have been profoundly marginalized during all five lessons, due to her tendency to produce very few actions or utterances without being directly prompted and guided to do so. While Emily was more involved in data collection when using the ILAB tools, she still required prompting from her partners and teacher.

In general, the intellectual and hands-on contributions of all four students were accepted by their lab groups, with some variations among lessons and among specific lab partners. In particular, Emily’s level of involvement varied substantially from lesson to lesson and was greatly dependent on the circumstances. For example, her relatively high involvement in Lesson 1 was due to frequent encouragement and guidance from her teacher, and her very low involvement in Lesson 2 was partially due to the microscale nature of the experiment.

Neil and Emily clearly took more data points and participated in a wider range of activities when using the ILAB tools than when not using the ILAB tools. Nate used whatever resources were available to him, along with his residual vision. Nate’s video task analysis revealed greater involvement in the N-lessons than might otherwise have naturally occurred, due to Lesson 1 incorporating the erroneous use of a notched syringe and Lesson 2 being a make-up lab with minimal involvement by his partner. It’s hard to say if Ryan took more data points when using the ILAB tools because of his eagerness to
use N-tools and I-tools alike, and because his AP physics labs were more about implementing concepts than about making observations and gathering data.

**Comparison of Graphic Analyses of Video Data**

The data illustrated in Figures 10-1 and 10-2 show the PTEs of the BLV students and sighted lab group partners for each school regarding the performance of laboratory-goal-directed actions during lab lessons. The BLV students are indicated in blue, and the sighted partners are indicated in red. For each school, Figure 10-1 shows the combined results of the two lessons conducted without the use of ILAB tools, while Figure 10-2 shows the combined results of the three lessons conducted with ILAB tools. The relative percentages for each school were rescaled based on the graphical data from the case studies in Chapters 6-9. This rescaling was performed to allow the pair of bars for each school in each figure to total 100%.
Figure 10-1: Percent of Time Engaged During N-Video Lab Lessons for BLV Students and Sighted Partners

Figure 10-2: Percent of Time Engaged During I-Video Lab Lessons for BLV Students and Sighted Partners
As seen in Figures 10-1 and 10-2, the BLV student at Badger High School contributed higher PTE (62.2) during the N-lessons than during the I-lessons (48.2), while the other three BLV students contributed higher PTEs during I-lessons as compared to N-lessons, with the results for the student at Rollinsville exhibiting the largest change (36.4 PTE for the N-lessons versus 66.8 PTE for the I-lessons). This may indicate that the usage of ILAB tools benefitted at least three of the four BLV students in the area of hands-on involvement in laboratory-goal-directed actions, with Neil at Rollinsville benefitting the most.

Various factors went into influencing these results, some of which were discussed within the individual case study chapters. At Badger High School, Nate’s residual vision allowed him to participate more in the N-lessons than if he had been completely blind and, in fact, he may have preferred relying on his limited eyesight to using the ILAB tools, which were new to him. He was used to depending on his residual vision and thus may have had some difficulty adjusting to the tools. Additionally, one of the N-lessons was a makeup lab, for which Nate’s partner served primarily as an observer and not an active participant, thus greatly increasing Nate’s combined PTE for the two N-lessons. However, during the I-lessons, Nate performed nearly half of the tasks in the experiments, representing a more evenly distributed PTE between Nate and his sighted partners, which may indicate the ILAB tools benefitted Nate even though his overall I-lesson PTE was lower than his overall N-lesson PTE.

In contrast, Ryan at Highland Hills was completely blind but had used the ILAB tools in previous science classes and so was very comfortable with them. Ryan also had excellent lab skills and was exceptionally intelligent and eager to participate in all labs,
both with and without ILAB tools. Additionally evident was the importance of planning which lab tasks would be performed by which individuals within his lab groups, as judicious planning resulted in high levels of PTE for Ryan regardless of whether ILAB tools were present.

While Neil at Rollinsville possessed residual vision, his much higher PTE for the I-lessons than for the N-lessons revealed a substantial improvement in hands-on laboratory participation when the ILAB tools were used. Like Ryan, he had used the tools in previous science classes. Using the JAWS speech output with the ILAB tools to complement his visual readings of laboratory instruments helped him confirm data points read from standard thermometers and other types of equipment. With this added channel of auditory information, Neil may have felt comfortable participating in lab activities during the I-lessons.

Regarding Emily at Twin Pines, her PTE scores for all lessons would have been lower had she not been repeatedly prompted by her classmates and TT Lindsey to become involved. In this way, her passive personality directly impacted her participation. However, having the ILAB tools made it possible for her to participate more fully than would otherwise have been the case. She had a great deal of hand-on-hand instruction from the teacher in one N-lesson, which artificially raised her PTE for that lesson, but she barely participated in the other N-lesson (and might not have participated at all had she been left unprompted). During the I-lessons, TT Lindsey mostly left it to Emily to figure out how best to use the ILAB tools. Emily was able to grasp ILAB tool functionality to some degree, but had difficulty with the more advanced functions of the JAWS/Logger Pro interface. She was able to take temperature and mass readings but could not
remember how the SALS worked and thus did not feel comfortable with its use. Overall, the ILAB tools allowed Emily to make observations, gather data, and perform quantitative tasks during labs, whereas her participation in lessons without ILAB tools primarily involved data recording and hand-on-hand instruction from the teacher. Thus, Emily’s improvement in PTE from her N-lessons to her I-lessons was both in increased time spent on laboratory-goal-directed actions and the range of tasks performed.

In comparing the results for the BLV students to those of the sighted students, the BLV students contributed overall higher PTEs than did the sighted students during the N-lessons at Badger and Highland Hills, but overall lower PTEs for Rollinsville and Twin Pines. With the I-lessons, the sighted students outperformed the BLV students in PTE at two of the schools (Badger and Twin Pines), but underperformed the BLV students at the other two schools (Highland Hills and Rollinsville). It is interesting to note that sighted students did not always outperform the BLV students in PTE either during labs with or without ILAB tools.

Figure 10-3 shows the combined N-lesson results and combined I-lesson results for the BLV students as compared to their sighted partners. This bar graph reveals that for the N-lessons, the sighted students slightly outperformed the BLV students (52.5 PTE versus 47.5 PTE), whereas for the I-lessons, the BLV students substantially outperformed their sighted partners (57.6 PTE versus 42.4 PTE). These data indicate that the ILAB tools allowed the BLV students to experience increased hands-on participation in laboratory-goal-directed activities as compared to lessons in which the ILAB tools were not used. While the amount of benefit varied among the participants, the ILAB intervention was beneficial for the BLV students as a group.
Comparison of Video Analysis Rubric Results

The ILAB video analysis rubric, described in Chapter 4 and detailed in Table 4-5, was developed for the purpose of collecting additional information for video data analysis, particularly regarding the levels of acceptance of the BLV students into their respective lab groups. The three raters – the external evaluator, independent rater, and the investigator – used the rubric to make various rankings while viewing all 20 of the ILAB videos included in this study (five videos from each of the four schools).

Inter-rater reliability was then determined through the use of Fleiss’ Kappa coefficient, as per the recommendation of a statistician. A separate Kappa coefficient was calculated for each item in the ILAB rubric. Fleiss’ Kappa coefficient values generally range from 0 to 1, with 1 indicating complete agreement. Negative values indicate that...
raters disagree more than could be accounted for by chance. The purpose of using Fleiss’ Kappa was to determine the level of consistency in the raters’ rankings of the individual rubric items. Of the eight rubric queries, three were binary yes/no items and five were Likert-scale items. Table 10-5 outlines the means of interpreting Fleiss’ Kappa coefficients, indicating the quality of agreement for each subscale of possible values.

Table 10-5: Interpretation of Fleiss’ Kappa Coefficients

<table>
<thead>
<tr>
<th>$\kappa$</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.00</td>
<td>Poor Agreement</td>
</tr>
<tr>
<td>0.00 - 0.20</td>
<td>Slight Agreement</td>
</tr>
<tr>
<td>0.21 - 0.40</td>
<td>Fair Agreement</td>
</tr>
<tr>
<td>0.41 - 0.60</td>
<td>Moderate Agreement</td>
</tr>
<tr>
<td>0.61 - 0.80</td>
<td>Substantial Agreement</td>
</tr>
<tr>
<td>0.81 - 1.00</td>
<td>Almost Perfect to Perfect Agreement</td>
</tr>
</tbody>
</table>

Source: Landis and Koch (1977)

The mean of our eight Fleiss’ Kappa coefficients was 0.240, on the lower end of the “fair” category. For the confidence interval, we calculated the mean $\pm t_{critical}$ multiplied by the standard error (Kuehl, 2000). $t_{critical}$ for a 95% confidence interval ($\alpha$ of 0.05) with $8 - 1 = 7$ df is 2.365. The standard error for the eight Kappa coefficients is 0.10252, so the confidence interval is $0.240 \pm (2.365 \times 0.10252)$, or $0.240 \pm 0.2424598$. More simply stated, the confidence interval is -0.0025 to 0.4825, indicating poor to moderate agreement. Table 10-6 shows the level of inter-rater reliability for each of the
eight rubric items. The binary yes/no questions were found to have moderate to substantial agreement among raters, and the Likert questions had poor to fair agreement.

Table 10-6: Inter-Rater Reliability Kappa Coefficients

<table>
<thead>
<tr>
<th>Rubric Item</th>
<th>Variable Type</th>
<th>Kappa</th>
<th>Strength of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Binary</td>
<td>0.425</td>
<td>Moderate</td>
</tr>
<tr>
<td>B</td>
<td>Binary</td>
<td>0.534</td>
<td>Moderate</td>
</tr>
<tr>
<td>C1</td>
<td>Likert</td>
<td>0.149</td>
<td>Slight</td>
</tr>
<tr>
<td>C2</td>
<td>Likert</td>
<td>0.011</td>
<td>Slight</td>
</tr>
<tr>
<td>C3</td>
<td>Likert</td>
<td>-0.171</td>
<td>Poor</td>
</tr>
<tr>
<td>C4</td>
<td>Likert</td>
<td>0.000</td>
<td>Slight</td>
</tr>
<tr>
<td>D</td>
<td>Likert</td>
<td>0.312</td>
<td>Fair</td>
</tr>
<tr>
<td>E</td>
<td>Binary</td>
<td>0.659</td>
<td>Substantial</td>
</tr>
<tr>
<td>Mean</td>
<td>Binary/Likert</td>
<td>0.240</td>
<td>Fair</td>
</tr>
</tbody>
</table>

Source: Adapted from Johnson and Fu (2010)

Rubric item A had moderate agreement among the raters when looking at findings from the four schools as a group. As seen in the individual case study chapters, Nate, Ryan, and Neil generally participated in lab group discussions more than did Emily, although Neil was exceptionally quiet during his N-lessons. Emily was the least involved in group discussions because of her quiet nature. Item B, as seen in the individual case study chapters and likewise with moderate agreement among the raters, revealed that the sighted students generally accepted the contributions of the BLV students, with the
exception of Neil during his N-lessons. Item E, with substantial inter-rater agreement, showed that the BLV students were often included in the collaborative participation of their lab groups, with Neil during his N-lessons presenting a particularly stark exception. For all three binary rubric items, Neil exhibited much improvement during his I-lessons, Nate had mild improvements, Ryan had mild declines, and Emily had mild improvements in A and E but no change in B.

Item C1 revealed high interest in the experiments for Nate and Ryan, with little difference between the scores for the N-lessons and I-lessons; and relatively low interest for Neil and Emily during the N-lessons. Emily exhibited little change in scores from N-lessons to I-lessons, but substantial improvement was seen for Neil, although his averaged C1 score for the I-lessons revealed him to be neither interested nor uninterested in the experiments. Of all the study participants, Emily had the lowest observed interest in her science experiments during the I-lessons. The inter-rater agreement for item C1 was categorized as slight.

Rubric item C2, also with slight inter-rater agreement, showed that the levels of interest of all four BLV students likely stayed much the same throughout the course of the individual experiments, with support for this statement being higher for Nate and Neil than for Ryan and Emily. Mild declines were also seen for Nate, Neil, and Emily from the N-lessons to the I-lessons, with a slight increase for Ryan. With poor inter-rater agreement, item C3 indicated that the levels of interest of the BLV students did not increase during the course of the individual lessons. Similarly, item C4, with slight inter-rater agreement, showed that the levels of interest of the BLV students did not decrease during the course of the individual lessons. Emily’s C4 scores are the highest among the
four study participants, indicating more of a possibility of a decrease in interest for Emily than for the other BLV students; however, her averaged N-lesson and I-lesson scores were both under 3, indicating a likelihood that her interest did not decrease.

Item D, with fair inter-rater agreement, showed that the techniques used by Nate and Ryan were perceived by their lab partners as beneficial both during their N-lessons and I-lessons, but with both students exhibiting declines for their I-lessons. Neil’s techniques were not perceived as beneficial for his N-lessons but were mildly seen as beneficial during his I-lessons. Averaged rater scores for Emily provided some indication that her lab partners’ perceptions of benefit shifted slightly toward the positive during the I-lessons as compared to the N-lessons, although her N-lesson and I-lesson scores were both essentially in the middle of the scale.

Table 10-7 compares the N-lesson scores with the I-lesson scores for each of the eight rubric items for the group of BLV participants as a whole. It can be seen that the group may have experienced improvements from the ILAB intervention for items A, B, C1, D, and E. Scores for item C2, which asked whether the level of interest remained the same throughout each experiment, were mildly confirmed by the low scores for C3 and C4, which asked if levels of interest increased or decreased, respectively.
Table 10-7: Averaged Group N-Lesson and I-Lesson Rubric Scores

<table>
<thead>
<tr>
<th>Rubric Item</th>
<th>N-Lessons</th>
<th>I-Lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.54</td>
<td>0.84</td>
</tr>
<tr>
<td>B</td>
<td>0.67</td>
<td>0.84</td>
</tr>
<tr>
<td>C1</td>
<td>3.17</td>
<td>3.50</td>
</tr>
<tr>
<td>C2</td>
<td>3.92</td>
<td>3.75</td>
</tr>
<tr>
<td>C3</td>
<td>2.21</td>
<td>2.44</td>
</tr>
<tr>
<td>C4</td>
<td>2.29</td>
<td>2.39</td>
</tr>
<tr>
<td>D</td>
<td>3.33</td>
<td>3.67</td>
</tr>
<tr>
<td>E</td>
<td>0.54</td>
<td>0.86</td>
</tr>
</tbody>
</table>

As seen earlier in Table 10-6, the Kappa coefficients for the eight rubric items revealed that item E had the highest inter-rater agreement. Next were items B, A, and D, in that order. The lowest agreement was found for C1, C2, C4, and C3. The lower Kappa coefficients for the Likert-scale queries were likely to have been at least partially caused by ambiguities in the terminology defining the set of five possible choices, although the binary yes/no items also contained ambiguities. One example is the use of the term “significantly” in rubric item A, which may have caused some confusion because significance can be subjective. Rubric item B, another yes/no question, asked if the sighted students “fully” accepted the contributions of the BLV student. This item may have been better presented as a Likert-type question because binary responses cannot account for partial acceptance. Item C3 conflated two concepts. This item, which asked if the level of interest of the BLV student increased during the experiments as a result of
understanding the material, did not provide for any possible increase in interest due to factors other than comprehension. Item C4, which asked whether “the level of interest exhibited by the BLV student decreased during the experiment due to losing interest in the activity,” seemed to inquire if the student lost interest as a result of losing interest. The intent had been to ask if the student lost interest as a result of boredom, although this would have also conflated two concepts, and would not have provided for decreased interest due to factors other than boredom. Item C4 was admittedly poorly constructed. Item D seems relatively clear in intent, and in fact yielded the highest inter-rater agreement of the Likert-type queries.

Even terms such as the word “interest” can be subjective and thus present some ambiguity since different raters may define the term differently. Also, interest is an internal attribute and may be expressed differently between individuals; it is thus not directly documentable since the raters could not say for sure what was going on in the minds of the BLV students. The raters were forced to base their ratings on what they saw and heard in the videos, and on their interpretations of what they perceived as interest or disinterest.

An additional factor is that the three raters had divergent educational backgrounds. While all were graduate students, the investigator was in chemistry, the external evaluator was in science education, and the independent rater was in educational psychology with an emphasis in special education. These differences in academic orientation may have further confounded the Likert-scale interpretations by means of influencing the raters’ decisions regarding what they each considered to be important.
Summary

Each of the four cases was examined for evidence of an effect resulting from participation in this study. Several data collection instruments were used, including student interviews, teacher interviews, the SAI II survey, audiovisual recordings, and the video analysis rubric. Information regarding school demographics, student background, teacher background, available classroom resources, types of lessons conducted, and the relationship between the investigator, teachers, BLV students, and parents was included to give additional meaning to the case studies.

The different types of data generally agreed with each other, but occasionally did not, such as with Emily’s post-school-year interview versus her SAI II scores. In her post-school-year interview, Emily indicated that her chemistry class had actually decreased her interest in science, but this was not seen in her SAI II results, which showed a slight improvement in attitude toward science.

Patterns and commonalities that were observed across the four cases through the use of the data collection instruments included the following:

1. As indicated during the student interviews, all four students felt that the ILAB tools helped them participate more in the hands-on aspects of their laboratory lessons. Three of the four agreed that the ILAB tools increased their overall participation during labs, increased their enjoyment of working with others to solve problems, helped them be more fully integrated and accepted into their lab groups, and increased their interest in studying science. All of the four indicated at least some positive effect from their participation in the ILAB project.
2. During the teacher interviews, the teachers agreed for the most part that the ILAB tools were helpful to the BLV students, but the degree of helpfulness was largely dependent on how well the students comprehended their use. All the teachers agreed that student efficacy in using the ILAB tools improved as the school year progressed. Three of the four agreed that the BLV students worked well in groups and experienced improvements in student interactions as the school year went on.

3. The SAI II did not yield statistically significant results but may have revealed personally significant results for two of the four participating BLV students.

4. The video task analyses revealed striking differences in personality among the BLV students, with Nate and Ryan exhibiting the greatest enthusiasm, comprehension, independence, and motivation during the lessons. Neil and Emily both tended to be quiet and passive, with Emily being more so than Neil. With the exception of Emily, the BLV students appeared motivated to become involved in the laboratory activities. Neil and Emily benefitted the most from their ILAB participation, spending more time involved in lab tasks and accomplishing a wider range of tasks during the ILAB lessons as compared to the non-ILAB lessons, but with Neil exhibiting somewhat more verbal and intellectual engagement in the tasks than did Emily. Emily’s understanding of the ILAB tools was the most limited. Ryan did very well both during N-lessons and I-lessons, and Nate did fairly well both during N-lessons and I-lessons.

5. The graphic analyses of PTE showed that, while Nate averaged a higher PTE in laboratory-goal-directed activities during the lessons not incorporating ILAB tools as compared to the lessons incorporating the tools, the other three BLV students
contributed higher averaged PTEs during I-lessons as compared to N-lessons, as was seen in Figures 10-1 and 10-2. The sighted lab partners slightly outperformed the BLV students in averaged PTE during the N-lessons, whereas the BLV students substantially outperformed their sighted lab partners during the I-lessons, as was seen in Figure 10-3. As also revealed in Figures 10-1 and 10-2, the sighted students did not consistently outperform the BLV students either in the N-lessons or the I-lessons when compared between schools.

6. The video analysis rubric rankings, as shown in Table 10-7, indicated that the BLV students as a group may have experienced improvements in their levels of acceptance into their lab groups and interest in the laboratory experiments during the I-lessons as compared to the N-lessons. However, substantial variation was noted between students, lessons, rubric items, and raters’ rankings.

Overall, Neil appeared to have benefitted the most from his participation in the ILAB study, as exhibited by his SAI II scores, video task analysis, graphic analysis, and rubric rankings. Ryan may have experienced the next highest benefit, as seen in his student interviews, teacher interview, and SAI II scores. Nate may have experienced a modest benefit, as seen in his student interviews, teacher interview, and rubric rankings. It’s unclear how much Emily may have benefitted, with some of her data sets indicating an improvement and other data sets indicating no improvement. While the amount of benefit varied among the participants and between individual lessons and types of data sets, the ILAB intervention appears to have been beneficial for the BLV students taken as a group.
Chapter 11

Discussion and Implications

The Independent Laboratory Access for the Blind (ILAB) project sought to develop and evaluate a suite of talking and audible hardware/software laboratory tools to empower blind and low-vision (BLV) students to have multisensory, hands-on science laboratory learning experiences. These tools were initially tested at residential schools for the blind, then later with BLV students enrolled in mainstream high school science courses. The qualitative and quantitative data gathered through several data collection instruments and presented in this report comprise the four case studies from the academic year 2007-08, the first year of testing in mainstream science laboratory classrooms. Premier among the ILAB tools was the JAWS/Logger Pro software interface, which made audible all information gathered through standard Vernier laboratory probes and visually displayed through Logger Pro.

While results were mixed, as discussed in Chapter 10, all four of the participating BLV students during 2007-08 seemed to have experienced at least some benefit, with the benefit being stronger for some than for others.

Support for the Hypotheses and Causal Map

The six hypotheses (Table 1-1 in Chapter 1) were explored by means of multiple data collection instruments and the resulting data sets, including student interviews, teacher interviews, the SAI II survey, audiovisual recordings, video task analyses, graphic analyses, and the video analysis rubric.
Hypothesis 1, which stated that the BLV students would be able to more fully participate in the science laboratory experience if provided with the ILAB tools, found substantial support in the data taken together as a whole. Not all data collection instruments were found to reveal support with respect to all the participating students, but all the students received some benefit, to a greater or lesser degree, as shown through at least some of the data sets.

Hypotheses 2, which proposed that BLV students would be able to contribute more productively to discussions in their laboratory groups when using the ILAB tools, found some support in the data regarding three of the students, but not the fourth.

Hypothesis 3 involved data collected primarily from two instruments: student pre/post interviews and the SAI II survey. This hypothesis – that BLV students would have greater interest in science and more positive attitudes toward science if they had a more hands-on laboratory experience through being provided with the ILAB tools – was supported qualitatively through the interview data for three of the students, and quantitatively by the SAI II survey data for two of the students individually, although no statistical significance was found for the SAI II data for the group of participants as a whole.

Hypothesis 4, which stated that participation in hands-on aspects of the science laboratory experience and integration into lab groups would be minimized when the ILAB tools were not used by the BLV students, was supported in some of the data sets for some of the students. The effect was found to be strong for two of the students and less so for the others.
Hypothesis 5, which stated that the BLV students would be more accepted into their lab groups when using the ILAB tools, was largely supported by the post-school-year student and teacher interviews and the rubric data.

Hypothesis 6, regarding whether the BLV students’ interest in STEM career paths would be more strongly cultivated if provided with ILAB tools than if not provided with the tools, was not fully explored in the data sets and found negative support in the post-year interview of one student.

The causal map (Figure 1-1 in Chapter 1) was also largely supported by the data, except for “Achievement,” “Understanding,” and “Choice of STEM Career,” none of which were well explored. However, as outlined in Chapter 3, increased hands-on involvement should result in improved achievement as well as improved peer acceptance. With the use of the ILAB tools, the BLV students filled hands-on roles beyond reading procedures and recording data. They collected data, manipulated equipment, solved problems, and helped with setup and clean up. In so doing, the hands-on participation of three of them increased, as seen in the graphic analyses, video task analyses, and interview transcripts. Improved acceptance in their lab groups was seen for three participants in the rubric results, and individual improvement in attitudes toward science was seen for two students in the SAI II results.

**Implications for Teaching**

The data presented in this report may have a number of implications for teaching science to students with BLV. The ILAB study has shown that assistive technologies such as those developed by ILAB can be successfully introduced into different levels of
mainstream chemistry and physics curricula, and that doing so carries multiple benefits for BLV students. These benefits include greater inclusion in the communities of practice represented by their lab groups, greater involvement in the hands-on accomplishment of laboratory goals, greater interest in science, and more positive attitudes toward science.

However, the preexisting attitudes, aptitudes, and personalities of individual students are major factors in how much benefit they may receive from having access to assistive technologies in science laboratory classrooms. For example, Nate was skilled in communicating with his lab partners and unhesitant to ask questions. Ryan was relatively quiet unless around people with whom he felt very comfortable, but exceptionally intelligent and eager to participate fully during laboratory lessons. Neil was very quiet and reserved, but willing to become more involved in lab tasks and thus experienced substantially increased involvement in tasks while using the ILAB tools. Emily exhibited little interest in science, laboratory work, lab group discussions, or the ILAB tools. No amount of encouragement from her teacher or group partners seemed to spark her interest in participating. She stoically tolerated the laboratory experience, remaining as quiet and inactive as her teacher and group partners would allow.

Perhaps among the most important implications for learning is that teachers should strive as much as possible to make the study of science seem compelling and interesting for their students. This would be true for all students, not just those with BLV. The special consideration for BLV students, however, is that preventing them from hands-on participation – either through neglecting their involvement or utilizing the directed laboratory assistant approach – can create fear of science and of the laboratory. It also must be recognized that some students naturally have little interest or aptitude for
science. However, these students still need grounding in the basics in order to be adequately educated for life as adults in a modern world.

Teachers should also understand that substantial training is required in the use of access tools such as those developed by ILAB, both for the students and the teachers (so that the teachers may assist the students with the tools if needed). Teacher training is also required regarding how to incorporate such tools into mainstream science curricula in order to achieve optimum benefit for students. These tools should help teachers encourage and facilitate hands-on learning experiences for BLV students that are similar to those of their sighted counterparts.

It is also important for science teachers with BLV students to consult disabilities services personnel at their schools regarding accommodations for the education of students with disabilities. Additionally, they should consult with the students themselves about their individualized limitations and access requirements. Instruction should be customized to individual students’ learning styles and needs, and science curricula should be adapted accordingly. Such adaptations are often relatively simple. However, most teachers in mainstream schools do not have specialized training in teaching students with disabilities; training in the use of the ILAB tools could help compensate for this lack of background. The goal is not to treat students with BLV as special cases, but to remove barriers to learning and make mainstream science education less restrictive and more inclusive of these students.
Limitations of the Study

A number of limitations to this study were revealed as work progressed, involving the hypotheses, various data collection instruments, data collection procedures, and equipment used.

The Hypotheses

In general, the hypotheses could have been worded and arranged more effectively for enhanced clarity. They also should be more directly related to each other and build on each other, instead of each being essentially a stand-alone statement. The importance of hands-on work to increased participation and inclusion should be explicitly stated first, since the rest of the hypotheses are founded on that concept. The current Hypothesis 3 is looking for two different types of results in a single statement and thus should be separated into two hypotheses. Hypothesis 4 should be placed at the end of the hypotheses because it is the only one about the negative condition, instead of appearing among hypotheses about the positive condition. Hypothesis 5 needs better wording, since “access” to the tools is insufficient in itself: The students also have to know how to use the tools and be willing to do so. Hypothesis 6 has the same problem with the “access” wording. Also, to more fully explore the viability of Hypothesis 6, the study would need to be redesigned to focus more on interests in STEM careers.

The Data Collection Instruments

All the data collection instruments exhibited limitations to a greater or lesser degree. Various improvements can and should be made in the future if further study of
the ILAB tools and implementation is to be conducted, or if any researchers would like to use similar data collection instruments for studying their own tools and techniques for teaching science to BLV students.

**Student and Teacher Pre/Post Interviews**

The interview questions should have been more closely tailored to reflect the causal map of this study (Figure 1-1). The causal map relates the key factors of the study, and the interview questions should have closely paralleled the causal map to seek answers directly related to these key points, as well as to how these points are related and build upon each other. Specifically, more questions should have been asked about the students’ interest in science and STEM careers. The questions also should be uniform from student to student and from teacher to teacher without variation in wording, to aid in direct comparison across participants.

**Scientific Attitude Inventory II**

The SAI II (Table 4-4 in Chapter 4; Moore and Foy, 1997) exhibited numerous difficulties regarding its reliability, as noted by earlier researchers (e.g., Munby, 1997; Brannan, 2004; Lichtenstein et al., 2008). Likewise as noted by the investigator, numerous of the 40 questions of the SAI II were ambiguous and may have been misinterpreted by the participating students.

For example, while item #1 (“I would enjoy studying science”) is straightforward and very clear in its intent, item #2 (“Anything we need to know can be found out through science”) is not nearly so straightforward and clear. This item is classified as a
negative statement, yet could be interpreted as hopeful and positive. Knowledgeable persons would recognize item #2 as an inaccurate statement, but a young and inexperienced person could regard faith in science as a positive attribute. Item #7 (“We can always get answers to our questions by asking a scientist”), another negative statement, could similarly be interpreted as saying that scientists are smart people and can provide lots of information.

Certain of the SAI II items also reveal a possible bias of the authors of the instrument toward pure science as opposed to applied science. Item #9 (“Electronics are examples of the really valuable products of science”) is classified as a negative statement. Similarly, item #24 (“A major purpose of science is to produce new drugs and save lives”) and item #31 (“A major purpose of science is to help people live better”) are classified as negative statements, while item #21 (“Ideas are the important result of science”) is classified as positive. Such classifications seem to indicate that Moore and Foy attached greater value to pure science than to applied science. But a large proportion of members of the public might think that the majority of pure science is accomplished with the intent that it will result in eventual useful applications.

These situations could have led some of the BLV students taking the SAI II to believe they were answering such questions positively, while actually their answers were tallied as negative. This may be one explanation of why Neil’s “positive” scores and “negative” scores both went up, as discussed in Chapter 8: Many of the items coded as positive were recognizable as being positive, but many of the items coded as negative could likewise have been interpreted as positive.
Some of the positive statements had ambiguities as well. Item #16 (“Scientific ideas can be changed”) and item #34 (“Scientists believe that nothing is known to be true for sure”), while recognized by knowledgeable persons as being true statements, could cause a child to wonder why they should care about scientific ideas if science is changeable and/or unknowable. Item #19 (“Some questions cannot be answered by science”) could indicate to a non-scientist or a child that science is a waste of time because questions are not answerable. Item #20 (“A scientist must have a good imagination to create new ideas”) could carry entirely different connotations from those intended, in that “imagination” can refer to the creation of entertaining fantasies.

Among Munby’s (1983) criticisms of the original SAI was the fact that the different items required three entirely different types of responses: analytical/empirical, social judgments (i.e., value statements), and emotional. He indicated doubt that such a mix of types of responses was actually measuring attitudes toward science, and said the SAI instead appeared in some cases to be gauging philosophical outlooks and personal opinions. The subsequently revised SAI – the SAI II (Moore and Foy, 1997) – unfortunately seems to incorporate much the same difficulties as did the original version. It should also be stated that the SAI II, in order to have any real expectation of functioning as intended, would have to be administered only to people with a preexisting solid understanding of science and scientific processes. A better plan of action may be to explore the efficacy of other instruments for measuring scientific attitudes.
**Audiovisual Recordings**

The position of the video camera in the various laboratory classrooms determined which actions were captured in the videos; only those actions within view of the camera lens were recorded. Actions that occurred off-camera could not be analyzed. In particular, one school often focused the camera closely on the benchtop and the hands of the students, and did not include a wider view of the workspace. Thus, many actions that were even only slightly out of the immediate area were not recorded; some of these videos had to be excluded from analysis. Camera angles were sometimes selected by a member of the ILAB team but more often were determined by the participating teachers and not always to the best result.

A related difficulty occurred when people did not respect the view of the camera angle; in other words, when lab partners (and occasionally teachers) stood in front of the camera (usually with their backs to it), thus blocking from view nearly everything relevant, sometimes for several minutes at a stretch.

Physical placement of the microphone determined the audio comments that were recorded; comments made too far away from the microphone were either unintelligible or not heard at all, and thus could not be factored into the analyses. Additionally, some teachers had difficulty correctly operating the Bluetooth microphones due to unfamiliarity with the technology, and some experienced malfunctions with the microphones. When the Bluetooth interface was not successfully attained, videos were without audio and could not be analyzed.
Additionally, video cameras sometimes were not turned on until partway into the laboratory lessons or, conversely, were either turned off or ran out of recording space prior to the end of lessons, resulting in incomplete audiovisual recordings.

**Transcript Analyses**

Transcription of the audiovisual recordings was done by a team of undergraduate students, with inconsistent results. Numerous difficulties were noted: different transcribers had different interpretations of what they saw and heard in the recordings; some transcribers were more or less detailed in their transcriptions than were others; some transcribers did not have as much efficacy using the NVivo video analysis software as would have been desirable; and not all transcribers were familiar enough with all the ILAB hardware to reliably recognize it onscreen. The transcripts would have likely been better had they all been done by the same person with an eye toward high quality, according to clearly demarcated and rigorously followed guidelines, although the transcriptions would have taken a single person hundreds of hours to complete.

As they are now, the transcripts do not consistently and fully represent the actions and utterances that occurred in the videos due to the independent interpretations of the undergraduate transcriptionists and their individual selectivity in what they chose to transcribe. This, of course, strongly affected the video task analyses and graphic analyses of the video data in this study. The transcripts, while flawed, were deemed to be sufficiently useable for this investigation, but future studies utilizing transcripts of audiovisual recordings would do well to seek greater consistency during transcribing.
Another limitation was that the investigator, being blind, was not able to be as close to the video data as he would have liked. While he could listen to the audio portion of the videos, he was forced to rely on the transcripts to understand the content.

**Video Analysis Rubric**

The video analysis rubric exhibited numerous shortcomings, as explained in Chapter 10. The rubric would need a substantial overhaul regarding clarification of the wording for the raters to be able to attain higher inter-rater reliability. Ambiguities inherent in the rubric likely contributed to differences in interpretation among the raters; more specific terminology would have aided the raters in their interpretations.

**ILAB Tool Training and Implementation**

The student and teacher participants during the academic year 2007-08, the first year of the ILAB study in mainstream schools, had the disadvantage of not having experienced adequate instruction and documentation on the operation of the ILAB tools, which impacted their implementation of the technology. Some of the teachers and students indicated frustration with the insufficient training and occasional malfunction of the tools. The students who were technologically savvy and had been exposed to the ILAB tools in previous courses tended to do better than those who had not. For years two and three of the ILAB study, the training modules were expanded and improved, and the technology refined, based on teacher/student feedback.

A related concern was the willingness of the BLV students to practice using the tools in advance of performing lab activities. As was noted by the investigator, the
students in this study who practiced with the tools had fewer difficulties using them during laboratory lessons than did those students who did not practice as much. It may even be that Emily’s limited mastery of the ILAB tools and resulting frustrations with the technology, due to not practicing with the devices after her initial training, contributed to her decrease in interest in science as mentioned during her post-year interview. While some guided practice occurred during student training modules, students need to practice on their own to retain and reinforce the knowledge gained during training.

**Color Recognition Technology**

Full implementation of the Color Analysis Laboratory Sensor (CALS) for color recognition has proven to be problematic. The device was consistent in indicating red-green-blue (RGB) values, but developing an algorithm for uniform recognition of other colors and combinations of colors has been difficult. More research and development will be needed to improve this device. While the CALS was used by the four participating BLV students in this study, it does not appear in any of the videos that were selected for analysis herein.

**Design of Study**

This study involved numerous variables, such as different students at different schools, using different ILAB tools for different lessons, with different teachers presenting different curricula. The enthusiasm of the participating students (and teachers) was highly variable from individual to individual, as was the interpersonal interaction styles and instruction styles of the teachers. How the ILAB tools were implemented in the
curricula varied from school to school, since implementation was largely left to the teachers. Also, different teachers had different time constraints on their busy schedules, which had an impact on how the tools were implemented. Better controls for these many types of variables would need to be instituted for future studies. One possibly uncontrollable variable, however, is that sometimes people behave differently when they know they are being observed. Another uncontrollable variable is the inherent differences in personalities of the participants.

**Future Research**

Further study will be necessary to confirm or improve upon the ILAB findings. Analysis of the data from years two and three of the ILAB study in mainstream schools is underway, but new investigations need to be conducted to continue to add to the body of research regarding how students with BLV can successfully participate in laboratory science on an equal basis with their sighted counterparts. These should include efficacy studies to determine how well various assistive technologies aid BLV students in science laboratory classes.

A related avenue of study would be how much the existence or nonexistence of residual vision affects the use of assistive technologies by students with BLV. For instance, Nate was able to employ his residual vision during the laboratory lessons, possibly causing him to depend on the ILAB tools to a lesser degree than he otherwise might have. This may indicate the ILAB tools could have greater benefits for students with no useable vision.
Additionally, more research is needed to develop tools to access the biological sciences. While traditional assistive tools for BLV students in biology classes – including tactile models, two-dimensional raised drawings, and live specimens – help teach a wide range of concepts and have been used as far back as 1924 at the California School for the Blind, more technological interfaces are required to create opportunities for BLV students to participate in biology laboratory instruction in the modern age. For example, gel electrophoresis is becoming a common methodology in high school and college biology laboratories, so the need exists for a technology to allow BLV students to measure the distance between spots on electrophoresis plates. Some of the ILAB tools used in chemistry and physics classes may be transferable to the study of biological sciences, but new assistive tools designed specifically for use in biology labs will also be needed.

**Potential Improvements to the ILAB Study**

If the ILAB study itself were to be continued and expanded, a new study design could control for many of the variables encountered. I would like to partner with a residential school for the blind to present opportunities for some of the students to take laboratory science classes in mainstream schools. In this way, there could be several students with BLV in classes with numerous sighted students, all with the same curriculum, same lessons, same teacher, same classmates. Mainstream science teachers at high schools located near residential schools for the blind may have already had a few students with BLV, and thus may possess some experience teaching the blind. Mechanisms for standardizing lab partner selection would have to be established, so that all BLV participants could have as similar a lab partner experience as possible.
Interviews could be conducted on a more regular basis throughout the school year, and I would strive to be in or near the classroom during lessons to immediately provide technical support and on-the-spot training as needed, since frustrations with the technology can create a negative experience for teachers and students alike. I would also be able to take field notes and record my reflections while activities were occurring. Preferably I would also have a sighted assistant to act as my eyes.

This study design would still not have the statistical power of a large sample size, but would substantially control for the variables and improve the case-study documentation of participants as they progress through the class. Again, some of the analyses would be quantitative and some would be qualitative. A combination of quantitative and qualitative analyses would be necessary to get a full picture. The new study design would incorporate greater consistency in data collection and analyses, and the quality of the data would be enriched. This, along with an improved set of hypotheses, should yield enlightening results. Specifics of the study would include:

1. Improved data collection instruments, as discussed earlier.
2. Several BLV students together in the same mainstream science class or in different sections of the same class, but each working with sighted partners and not with each other.
3. Same ILAB training module for all BLV participants and teachers.
4. Same curriculum for all BLV participants, with the same textbooks and lessons.
5. Same teachers for all BLV participants, to eliminate variations in teaching styles and classroom resources.
6. Clearly defined and standardized feedback mechanisms for BLV students and teachers.

7. Direct onsite support provided by ILAB personnel to assist in appropriate implementation of the tools in the science curriculum and troubleshooting of the technology as needed.

8. One dedicated assistant, instead of a team of assistants, to help with data analysis, to ensure consistency in data graphing, charting, and presentation.

**Future of the ILAB Tools**

In February 2009, I launched Independence Science, LLC, to commercialize the JAWS/Logger Pro interface and other ILAB tools, and act as a distributorship for the Vernier laboratory probeware. My goal is to make the ILAB tools and other assistive technologies available to schools, educators, and BLV individuals across the U.S. I also wish to develop new technologies and methodologies in the future, to continue to make laboratory science more accessible to students with BLV. New technologies are expected to include Logger Pro interfaces with screen-reader programs other than JAWS and a portable data collection device that can be used in the field.

Additionally, Independence Science has partnered with the National Center for Blind Youth in Science (NCBYS) to help provide the necessary educational opportunities for blind youth to be able to pursue careers in STEM. The ILAB tools will also continue to be used at NFB Youth Slam events, which are week-long summer science camps held in odd-numbered years for approximately 200 BLV high school students.
Conclusions

The ILAB tools have been shown to offer benefits for the laboratory science education of high school students with BLV. Positive effects were found in all types of data sets, although positive results were not evenly distributed across data collection instruments and participating students. Five of the six hypotheses found at least some support among the data to a greater or lesser degree, although all the hypotheses would need to be reworked if used again in the future. The causal map likewise was mostly supported by the data, although a few items on the map were not adequately explored. The rubric data showed that the participating students as a group were somewhat more included in the communities of practice represented by their lab groups during lessons incorporating the ILAB tools as compared to those not incorporating the tools, although the effect was not consistently found for all the students individually.

The major messages to be taken from this study include the following:

1. Multisensory tools are necessary for BLV students to be able to learn science on an equivalent basis with their sighted peers, and such tools can be implemented in mainstream science classrooms. Many of the tools and methodologies (including the directed laboratory assistant approach) developed by earlier researchers are inadequate for contemporary students in modern laboratory classrooms. The ILAB tools offer sophisticated methods of observing, analyzing, and interpreting scientific data.

2. Further tool advancements are necessary to enable BLV students to truly function independently in laboratories, and ongoing advancements will be necessary to keep up with technological changes in classrooms. This will make the ILAB
devices an even more powerful suite of talking and audible tools for BLV students in science classrooms.

3. Assistive technologies such as the ILAB tools are not plug-and-play items, and require willingness on the part of teachers and BLV students to learn how to use them. The tools require a strong element of intrinsic motivation on the part of users because the tools do not provide extrinsic motivation.

4. Differences in personality pose a major factor in the efficacy of students with the ILAB tools, in that students who are motivated to learn science and to use the tools are much more likely to benefit from them than are students who are staunchly uninterested in science or the ILAB devices. In short, you can give a student the SALS, but you cannot make the student want to use it.

5. The inherent potential of many persons with disabilities is currently too often neglected. Most persons with BLV, and persons with other disabilities, are master problem solvers out of sheer necessity, having spent their lives learning innovative ways to compensate for their limitations. Problem solving is the essence of science, and the entire spectrum of the sciences can always use expert problem solvers. Making participation in the sciences more accessible to persons with disabilities could encourage a new contingent of lifelong problem solvers to enter the STEM professions – to the benefit of the sciences and of society.

Similarities of this investigation to previous work in this area include the use of case studies. Most previous works focused on adaptations made by a particular teacher or small group of teachers who then presented a set of tips or suggestions; others focused on
how a particular student fared as a result of adaptations. I would call both types of earlier approaches “case studies” in a loose sense of the term. However, my work was different from that of most earlier efforts in that it was a rigorous, formalized research investigation. The ILAB tools were also more technologically advanced and capable of more precise quantitative measurements than were earlier tools, in keeping with the technological requirements of today’s mainstream science classrooms. Further, my exhaustive review of the literature revealed very few other studies in which the researchers both developed new tools and rigorously studied their efficacy.

This study admittedly had numerous flaws but, hopefully, what I learned from my mistakes will help future researchers avoid similar pitfalls. What is clear is that the four participating BLV students discussed in this report had a richer set of experiences in laboratory science with the ILAB tools than they did without the tools, as shown in various of the data sets. Even Emily, who indicated during her post-year interview that her interest in science had decreased as a result of her chemistry class, also said she enjoyed having had greater hands-on participation during the labs.

With appropriate and up-to-date access technologies to empower BLV students to independently conduct science explorations and to more fully integrate into their lab groups, such students will be able to informatively decide whether or not to pursue career paths in the STEM professions rather than just resign themselves to being marginalized in their laboratory classes and excluded from careers in the sciences.
REFERENCES


Chand, Rajni K. Same Size Doesn’t Fit All: Insights from Research on Listening Skills at the University of the South Pacific (USP). *International Review of Research in Open and Distance Learning 2007, 8* (3), 1-22.


Collier, David; Seawright, Jason; Brady, Henry E. Qualitative Versus Quantitative: What Might This Distinction Mean? In *Workshop on Scientific Foundations of Qualitative Research*; Ragin, Charles C., Nagel, Joanne, White, Patricia, Eds.; National Science Foundation: Arlington, VA, 2004; pp 71-76.


Donalson, Kathleen. *Opportunities Gained and Lost: Perceptions and Experiences of Sixth Grade Students Enrolled in a Title I Reading Class*. Ph.D. Dissertation, Texas Tech University, Lubbock, TX, 2008.


Ely, Richard; Emerson, Robert Wall; Maggiore, Theresa; Rothberg, Madeleine; O’Connell, Trisha; Hudson, Laurel. Increased Content Knowledge of Students with Visual Impairments As a Result of Extended Descriptions. *J. of Special Education Tech.* 2006, 21 (3), 31-43.


Kozma, Robert; Chin, Elaine; Russell, Joel; Marx, Nancy. The Role of Representations and Tools in the Chemistry Laboratory and Their Implications for Chemistry Learning. *J. of the Learning Sciences* **2000**, 5 (2), 105-143.


McPhail, Jean C; Pierson, Joanne M.; Freeman, John G.; Goodman, Julie; Ayappa, Arati. The Role of Interest in Fostering Sixth Grade Students’ Identities As Competent Learners. *Curriculum Inquiry* **2000**, *30* (1), 43-70.


Mukamusoni, Dariya. Distance Learning Program of Teachers at Kigali Institute of Education: An Expository Study. *International Review of Research in Open and Distance Learning* 2006, 7 (2), 1-10.


Stefanich, G.P.; Norman, K.I. Teaching Science to Students with Disabilities: Experiences and Perceptions of Classroom Teachers and Science Educators; Association for the Education of Teachers in Science: Washington, D.C., 1996.


Supalo, Cary; Kreuter, Rodney A.; Musser, Aaron; Han, Josh; Briody, Erika; McArtor, Chip; Gregory, Kyle; Mallouk, Thomas E. Seeing Chemistry through Sound: A Submersible Audible Light Sensor for Observing Reactions in Real Time. *Assistive Technology Outcomes and Benefits* 2006, 3 (1), 110-116.


Appendix A:

About the Investigator

Cary A. Supalo has been blind since the age of seven, when he lost his eyesight as the result of a blood vessel hemorrhage in his only good eye. His other eye had been removed when he was only 18 months old. Upon the loss of his primary vision, he was able to see shapes, perceive color, and read large print for a number of years. At age 17 he lost his remaining useable vision and was determined to be completely blind.

He travels from place to place with the aid of a white cane. He uses American English Braille to read and write notes. He also uses several types of assistive technologies widely available to persons with blindness or low vision (BLV). Specialized blindness skills training helped give him his independence in everyday life.

Supalo went to Purdue University for his undergraduate education, earning degrees both in chemistry and communications because he felt a scientist should be able to communicate well with peers, students, and the public. During his master’s degree studies in inorganic chemistry at Penn State, during which he conducted research in catalysis, he worked with undergraduate students who assisted him in library research, manipulating laboratory equipment, and chemicals handling. But since catalysis is highly sensitive to even slight variations in technique, this approach resulted in large inconsistencies in the data collected. As a result, he became deeply interested in developing multisensory hardware and software to help BLV persons operate independently in conducting laboratory research. Thus, he cofounded the Independent Laboratory Access for the Blind (ILAB) project at Penn State in 2004.
The ILAB tools were field tested for five years, both in residential schools for the blind and mainstream high schools. Supalo is currently working to make these tools commercially available. In February 2009 he founded and serves as president of Independence Science, LLC, a business offering technological consulting services and assistive hardware/software to school districts, state rehabilitation agencies, parents and students, and colleges/universities to help BLV students have hands-on science learning experiences. The company also disseminates assistive technologies as a licensed distributor of Vernier Software & Technology products.

Supalo has authored or coauthored articles in academic journals, coordinated and presented workshops and symposia throughout the U.S., given several invited presentations on ILAB tools and methodologies, and spoken at numerous scientific, educational, and assistive technology conferences at national and regional levels. He is a member of the American Chemical Society (ACS) and has served on the ACS Chemists with Disabilities Committee since 2005. In 2000 he was named an NSF Graduate Research Fellow Honorable Mention, and in 2008 accepted the Chemistry Luminary Award on behalf of the Central Pennsylvania Local Section of ACS for organizing an ILAB Open House and ILAB Teacher Training Workshop. He was also a 2009 recipient of a Graduate Student Research Silver Award from the Materials Research Society, for “significant and timely research” presented at the 2009 MRS Fall Meeting.

Supalo is an active member of the National Federation of the Blind (NFB) and served as a local chapter president for several years. He has been a member of the NFB’s Research and Development Committee since 2005. He also served as co-principal investigator regarding content evaluation and information dissemination for the NFB
Jernigan Institute’s www.BlindScience.org, an NSF-funded project to help educators share ideas about methods for teaching BLV students.

Supalo has always had a passion for working with persons with BLV or other disabilities, especially when it comes to mentoring them in science, technology, engineering, and mathematics (STEM). His hope is to encourage more of these individuals to consider STEM career paths. He believes the pursuit of science should be available to all, not just to the able-bodied, and he continues to work toward this goal.

*Note:* In this dissertation, Supalo often elected to use the terms “BLV students” or “blind persons” or similar phrasing, even though such phrasing is generally considered politically incorrect. Many people prefer “students with BLV” or “persons with blindness” because they believe this places the emphasis on the individual rather the disability. Supalo considers blindness or low vision to be just a characteristic that, with proper training and adaptive methodologies, can be reduced to little more than a nuisance. From this point of view, and in agreement with the NFB, he thinks the characteristic can legitimately be named before the person in a simple adjectival phrase. His particular choice of phrasing is due to personal preference and a desire to avoid awkward wording, and he does not intend to offend any readers. Out of respect, however, when discussing literature written by the various authors cited throughout this document, Supalo used politically correct terminology when the authors themselves used it.
Appendix B:

Approved Consent Forms

The following are examples of five types of consent forms that were approved by the Institutional Review Board (IRB) in Pennsylvania State University’s Office of Research Protections (ORP). Approvals from all participants were required prior to any data collection.

The five types of forms are:

- Informed Consent Form for Social Science Research – Blind or Low Vision Student
- Informed Consent Form for Social Science Research – Parent of Blind or Low Vision Student
- Informed Consent Form for Social Science Research – Sighted Student
- Informed Consent Form for Social Science Research – Parent of Sighted Student
- Individual Investigator Agreement – Participating Teacher
Title of Project: Using Talking and Audible Laboratory Tools in a Mainstream High School Science Classroom

Principal Investigator: Cary Supalo
104 Chemistry Research Building, Box 280
University Park, PA 16802

Advisor: Tom Mallouk
104 Chemistry Research Building, Box 510
University Park, PA 16802

1. Purpose of the Study: The purpose of this research is to evaluate how speech-accessible tools can allow low vision students to participate independently in a laboratory setting. High school students such as yourself are being sought as participants in the study.

2. Procedures to be followed: You will first be asked to learn how to use the JAWS screen reading software interface with the LoggerPro software, which will take approximately two hours. You or your partner will perform high school laboratory experiments using tools designed to allow blind and low vision students to participate independently in classroom science labs. The experiment sessions will be videotaped. The procedures for each experiment are included in your science textbook. You will be asked to complete a forty question survey at the beginning and the end of the school year. You will also be interviewed at the beginning, middle, and end of the year and asked questions regarding how the class is going and how the tools are helping with class participation. You may also be asked if the researcher can use your journal for research purposes. The journal documents your feelings about how the tools are helping or hindering in the classroom as well as your general feelings towards science.

3. Recordings: Video recordings will be made of the laboratory sessions, and will be kept by your teacher in secure storage in his office until they are picked up and transported to Penn State by Cary Supalo, where they will be kept in secure storage in a safe in a locked office (Room 222) of the Chemistry Research Building. Your teacher and Cary Supalo will have access to these video recordings. In addition, Cary Supalo will audio record personal interviews, and he will be the only person with access to them. Recordings will be destroyed by October 31, 2011.

The following may review and copy records related to this research: The Office of Human Research Protections in the U.S. Department of Health and Human Services, the Social Science Institutional Review Board and the PSU Office for Research Protections.
4. Discomforts and Risks: There are no risks in participating in this research beyond those experienced in everyday life. Some of the questions, such as speaking about your visual impairment could be personal, but at no time are you required to answer any question if you do not want to.

The risks involved are no greater than any risks faced by a typical high school student in a high school science laboratory. A computer program known as Job Access for Windows (JAWS), will provide audible access to numerical information on the computer screen by reading the data aloud. Notched syringes will be used, which are designed to allow a blind student to measure volumes of liquid more accurately than is possible using the traditional graduated cylinder, and also pour it more easily, but these syringes will not have needles or any sharp points attached in any way. The possibility of a beaker with a liquid in it being pushed off a table is possible, and is reduced by placing the beaker on a non-slip surface such as a piece of rubber or damp paper towels. This risk is not any more or less for blind students than sighted students.

In the unlikely event you become injured as a result of your participation in this study, medical care is available. It is the policy of this institution to provide neither financial compensation nor free medical treatment for research related injury.

5. Benefits: By eliminating the need for a sighted assistant, blind and low vision students will have the opportunity to develop a passion for scientific experimentation, and will better develop the confidence and skills that promote the choice of a career in science. Because blind and low vision persons are presented with accessibility challenges in their everyday lives, they have a great deal of experience in problem-solving. It is believed that this project will have social benefits by encouraging blind and low vision persons to pursue careers in the sciences, where their problem solving skills will be a great asset.

6. Duration/Time: This research will take place over the course of the school year. The interviews (up to 3) may take up to 30 minutes each. The survey (2) will take about 15-20 minutes each. Journal entries may take up to 5-10 minutes for each entry.

7. Statement of Confidentiality: Your participation in this research is confidential. The data will be stored and secured at the Chemistry Research Building, Room 222, in a locked file cabinet. The following may review and copy records related to this research: The Office of Human Research Protections in the U.S. Department of Health and Human Services, the Social Science Institutional Review Board and the PSU Office for Research Protections. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared.

8. Right to Ask Questions: You can ask questions about this research. Contact Cary Supalo with questions, complaints or concerns about the research. You can also call if you feel this study has harmed you. If you have questions about your rights as a research participant, or you have concerns or general questions research, contact Penn State University’s Office for Research Protections at (814) 865-1775.

9. Voluntary Participation: Your decision to be involved in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise.
If you are under 18, you will also need the consent of a parent or legal guardian to take part in this study. There is a separate consent form for parents/legal guardians to sign. If you understand the above information and agree to take part in this study, please sign your name below.

You will be given a copy of this signed and dated consent form for your records.

*May the researcher use your coursework, journal entries, or other information for research purposes?*

Please choose one response.

- [ ] I DO give permission to have my classroom work included in this study
- [ ] I DO NOT give permission to have my classroom work included in this study

*May the researcher audio and/or video tape you performing the experiments for research purposes?*

Please choose one response.

- [ ] I DO give my permission to be audio/video taped.
- [ ] I DO NOT give my permission to be audio/video taped.

______________________________    _____________________
Student Signature            Date

______________________________    _____________________
Person Obtaining Consent        Date
Informed Consent Form for Social Science Research – Parent of Blind or Low Vision Student
The Pennsylvania State University

Title of Project: Using Talking and Audible Laboratory Tools in a Mainstream High School Science Classroom

Principal Investigator: Cary Supalo
104 Chemistry Research Building, Box 280
University Park, PA 16802

Advisor: Tom Mallouk
104 Chemistry Research Building, Box 510
University Park, PA 16802

1. Purpose of the Study: The purpose of this research is to evaluate how speech-accessible tools can allow low vision students to participate independently in a laboratory setting. High school students like your child are being sought as participants in the study.

2. Procedures to be followed: Your son/daughter will be asked to perform high school laboratory experiments using tools designed to allow blind and low vision students to participate independently in classroom science labs. The experiment sessions will be videotaped. The procedures for each experiment are included in your child's science textbook. Your child will be asked to complete a forty question survey at the beginning and the end of the school year. Your child may also be interviewed at the beginning, middle, and end of the year and asked questions about how the class is going and how the tools are helping with class participation. Your child may also be asked if the researcher can use his/her journal for research purposes. The journal documents his or her feelings about how the tools are helping or hindering in the classroom, as well as their general feelings towards science.

3. Recordings: Video recordings will be made of the laboratory sessions, and will be kept by the teacher in secure storage in the teacher’s office until they are picked up and transported to Penn State by Cary Supalo, where they will be kept in secure storage in a safe in a locked office (Room 222) of the Chemistry Research Building. The teacher and Cary Supalo will have access to these video recordings. In addition, Cary Supalo will audio record personal interviews, which only he will have access to. Recordings will be destroyed by October 31, 2011.

4. Discomforts and Risks: There are no risks in participating in this research beyond those experienced in everyday life. Some of the questions, such as speaking about one's visual impairment, are personal.

The risks involved are no greater than any risks faced by a typical high school student in a high school science laboratory. A computer program known as Job Access for Windows (JAWS), will provide audible access to numerical information on the computer screen by reading the data aloud. Notched syringes will be used, which are designed to allow a blind student to measure volumes of liquid more accurately than is possible using the traditional graduated cylinder, and also pour it more easily, but
these syringes will not have needles or any sharp points attached in any way. The possibility of a beaker with a liquid in it being pushed off a table is possible, but is reduced by placing the beaker on a non-slip surface such as a piece of rubber or damp paper towels. This risk is not any more or less for blind students than sighted students.

In the unlikely event your child becomes injured as a result of your participation in this study, medical care is available. It is the policy of this institution to provide neither financial compensation nor free medical treatment for research related injury.

5. Benefits: By eliminating the need for a sighted assistant, blind and low vision students will have the opportunity to develop a passion for scientific experimentation, and will better develop the confidence and skills that promote the choice of a career in science. Because blind and visual impaired persons are presented with accessibility challenges in their everyday lives, they have a great deal of experience in problem-solving. It is believed that this project will create social benefits by encouraging blind and low vision persons to pursue careers in the sciences, where their problem solving skills will be a great asset.

6. Duration/Time: This research will take place over the course of the school year. The interviews (up to 3) may take up to 30 minutes each. The survey (2) will take about 15-20 minutes each. Journal entries may take up to 5-10 minutes for each entry.

7. Statement of Confidentiality: Your child's participation in this research is confidential. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared. The following may review and copy records related to this research: The Office of Human Research Protections in the U.S. Department of Health and Human Services, the Social Science Institutional Review Board and the PSU Office for Research Protections.

8. Right to Ask Questions: You or your child can ask questions about this research. Contact Cary Supalo with questions, complaints or concerns about the research. You can also call if you feel this study has harmed you. If you have questions about your rights as a research participant, or you have concerns or general questions about research, contact Penn State University’s Office for Research Protections at (814) 865-1775.

9. Voluntary Participation: You and your child's decision to participate in this research is voluntary. Your child can stop at any time. He or she does not have to answer any questions that he or she does not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits your or your child would otherwise receive. You will be given a copy of this signed and dated consent form for your records.

May the researcher use your child’s coursework, journal entries, or other information for research purposes?
Please choose one response.

I DO give my consent to have my child’s classroom work included in this study
I DO NOT give my consent to have my child’s classroom work included in this study
May the researcher audio and/or video tape your child performing the experiments for research purposes?

Please choose one response.

_______ I DO give my permission for my child to be audio/video taped.

_______ I DO NOT give my permission for my child to be audio/video taped.

I give permission for my child, _____________________________, to participate in this research project.

_____________________________________________              _____________________
Parent or Legal Guardian Signature                                                Date

_____________________________________________              _____________________
Person Obtaining Consent                                                               Date
Title of Project: Using Talking and Audible Laboratory Tools in a Mainstream High School Science Classroom

Principal Investigator: Cary Supalo
104 Chemistry Research Building, Box 280
University Park, PA 16802

Advisor: Tom Mallouk
104 Chemistry Research Building, Box 510
University Park, PA 16802

1. Purpose of the Study: The purpose of this research is to learn more about how speech-accessible tools can allow low vision students to participate independently in a laboratory setting. High school students such as yourself are being sought as participants in the study.

2. Procedures to be followed: You or your partner will perform high school laboratory experiments using tools designed to allow blind and low vision students to participate independently in classroom science labs. The experiment sessions will be videotaped. The procedures for each experiment are included in your science textbook. Your may be asked to complete a forty question survey at the beginning and the end of the school year. You may also be interviewed at the beginning, middle, and end of the year and asked questions regarding how the class is going and how the tools are helping with class participation.

3. Recordings: Video recordings will be made of the laboratory sessions, and will be kept by the teacher in secure storage in his office until they are picked up and transported to Penn State by Cary Supalo, where they will be kept in secure storage in a safe in a locked office (Room 222) of the Chemistry Research Building. The teacher and Cary Supalo will have access to these video recordings. In addition, Cary Supalo will audio record personal interviews, which only he will have access to. Recordings will be destroyed by October 31, 2011.

4. Discomforts and Risks: There are no risks in participating in this research beyond those experienced in everyday life. Some of the questions, such as speaking about visual impairment, could be personal but at no time are you required to answer any question if you do not want to.

The risks involved are no greater than any risks faced by a typical high school student in a high school science laboratory. Some students will be using a computer program known as Job Access for Windows (JAWS), which will provide audible access to numerical information on the computer screen by reading the data aloud. Notched syringes will be used, which are designed to allow a blind student to measure volumes of liquid more accurately than is possible using the traditional graduated cylinder, and also pour it more easily, but these syringes will not have
needles or any sharp points attached in any way. The possibility of a beaker with a liquid in it being pushed off a table is possible, and is reduced by placing the beaker on a non-slip surface such as a piece of rubber or damp paper towels. This risk is not any more or less for blind students than sighted students.

In the unlikely event you become injured as a result of your participation in this study, medical care is available. It is the policy of this institution to provide neither financial compensation nor free medical treatment for research related injury.

5. Benefits: By eliminating the need for a sighted assistant, blind and low vision students will have the opportunity to develop a passion for scientific experimentation, and will better develop the confidence and skills that promote the choice of a career in science. Because blind and low vision persons are presented with accessibility challenges in their everyday lives, they have a great deal of experience in problem-solving. It is believed that this project will have social benefits by encouraging blind and low vision persons to pursue careers in the sciences, where their problem solving skills will be a great asset.

6. Duration/Time: This research will take place over the course of the school year. The interviews (up to 3) may take up to 30 minutes each. The survey (2) will take about 15-20 minutes each. Journal entries may take up to 5-10 minutes for each journal entry.

7. Statement of Confidentiality: Your participation in this research is confidential. The data will be stored and secured at the Chemistry Research Building, Room 222, in a locked file cabinet. The following may review and copy records related to this research: The Office of Human Research Protections in the U.S. Department of Health and Human Services, the Social Science Institutional Review Board and the PSU Office for Research Protections. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared.

8. Right to Ask Questions: You can ask questions about this research. Contact Cary Supalo with questions, complaints or concerns about the research. You can also call if you feel this study has harmed you. If you have questions about your rights as a research participant, or you have concerns or general questions about research, contact Penn State University’s Office for Research Protections at (814) 865-1775.

9. Voluntary Participation: Your decision to be involved in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise. If you are under 18, you will also need the consent of a parent or legal guardian to take part in this study. There is a separate consent form for parents/legal guardians to sign.

If you understand the above information and agree to take part in this study, please sign your name below.

You will be given a copy of this signed and dated consent form for your records.
May the researcher use your coursework, journal entries, or other information for research purposes?
Please choose one response.

[ ] I DO give permission to have my classroom work included in this study
[ ] I DO NOT give permission to have my classroom work included in this study

May the researcher audio and/or video tape you performing the experiments for research purposes?
Please choose one response.

[ ] I DO give my permission to be audio/video taped.
[ ] I DO NOT give my permission to be audio/video taped.

_____________________________________________  _____________________
Student Signature      Date

_____________________________________________               _____________________
Person Obtaining Consent      Date
Informed Consent Form for Social Science Research – Parent of Sighted Student
The Pennsylvania State University

Title of Project: Using Talking and Audible Laboratory Tools in a Mainstream High School Science Classroom

Principal Investigator: Cary Supalo
104 Chemistry Research Building, Box 280
University Park, PA 16802

Advisor: Tom Mallouk
104 Chemistry Research Building, Box 510
University Park, PA 16802

1. Purpose of the Study: The purpose of this research is to evaluate how speech-accessible tools can allow low vision students to participate independently in a laboratory setting. High school students like your child are being sought as participants in the study.

2. Procedures to be followed: Your child will be asked to perform high school laboratory experiments using tools designed to allow blind and low vision students to participate independently in classroom science labs. The experiment sessions will be videotaped. The procedures for each experiment are included in your child's science textbook. Your child may be asked to complete a forty question survey at the beginning and the end of the school year. Your child may also be interviewed at the beginning, middle, and end of the year and asked questions regarding how the class is going and how the tools are helping with class participation. Your child may also be if the researcher can use his/her journal for research purposes. The journal documents his or her feelings about how the tools are helping or hindering in the classroom as well as their general feelings towards science.

3. Recordings: Video recordings will be made of the laboratory sessions, and will be kept by the teacher in secure storage in the teacher’s office until they are picked up and transported to Penn State by Cary Supalo, where they will be kept in secure storage in a safe in a locked office (Room 222) of the Chemistry Research Building. The teacher and Cary Supalo will have access to these video recordings. In addition, Cary Supalo will audio record personal interviews, which only he will have access to. Recordings will be destroyed by October 31, 2011.

4. Discomforts and Risks: There are no risks in participating in this research beyond those experienced in everyday life. Some of the questions, such as speaking about visual impairment, are personal.

The risks involved are no greater than any risks faced by a typical high school student in a high school science laboratory. Some students will use a computer program known as Job Access for Windows (JAWS), which will provide audible access to numerical information on the computer screen by reading the data aloud. Notched syringes will be used, which are designed to allow a blind student to measure volumes of liquid more accurately than is possible using the traditional graduated cylinder, and also pour it more easily, but these syringes will not have needles or any sharp points attached in
any way. The possibility of a beaker with a liquid in it being pushed off a table is possible, but is reduced by placing the beaker on a non-slip surface such as a piece of rubber or damp paper towels. This risk is not any more or less for blind students than sighted students.

In the unlikely event your child becomes injured as a result of his/her participation in this study, medical care is available. It is the policy of this institution to provide neither financial compensation nor free medical treatment for research related injury.

5. Benefits: By eliminating the need for a sighted assistant, blind and low vision students will have the opportunity to develop a passion for scientific experimentation, and will better develop the confidence and skills that promote the choice of a career in science. Because blind and visually impaired persons are presented with accessibility challenges in their everyday lives, they have a great deal of experience in problem-solving. It is believed that this project will create social benefits by encouraging blind and low vision persons to pursue careers in the sciences, where their problem solving skills will be a great asset.

6. Duration/Time: This research will take place over the course of the school year. The interviews (up to 3) may take up to 30 minutes each. The survey (2) will take about 15-20 minutes each. Journal entries may take up to 5-10 minutes for each entry.

7. Statement of Confidentiality: You and your child's participation in this research is confidential. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared. The following may review and copy records related to this research: The Office of Human Research Protections in the U.S. Department of Health and Human Services, the Social Science Institutional Review Board and the PSU Office for Research Protections.

8. Right to Ask Questions: You or your child can ask questions about this research. Contact Cary Supalo with questions, complaints or concerns about the research. You can also call if you feel this study has harmed you. If you have questions about your rights as a research participant, or you have concerns or general questions about research, contact Penn State University’s Office for Research Protections at (814) 865-1775.

9. Voluntary Participation: Your child's decision to participate in this research is voluntary. Your child can stop at any time. He or she does not have to answer any questions that he or she does not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you and your child would otherwise receive.

You will be given a copy of this signed and dated consent form for your records.

May the researcher use your child’s coursework, journal entries, or other information for research purposes?

Please choose one response.

_______ I DO give my consent to have my child’s classroom work included in this study

_______ I DO NOT give my consent to have my child’s classroom work included in this study
May the researcher audio and/or video tape your child performing the experiments for research purposes?

Please choose one response.

________ I DO give my permission for my child to be audio/video taped.

________ I DO NOT give my permission for my child to be audio/video taped.

I give permission for my child, _____________________________, to participate in this research project.

_____________________________________________               _____________________

Parent or Legal Guardian Signature                                                 Date

_____________________________________________               _____________________

Person Obtaining Consent                                    Date
Individual Investigator Agreement
The Pennsylvania State University

Name of Institution with the Federalwide Assurance (FWA): The Pennsylvania State University

Applicable FWA #: FWA00001534

Individual Investigator’s Name: ____________________________________________________

Specify Research Covered by this Agreement: IRB#24587 titled Independent Laboratory Access for Blind and Low Vision Students in the Mainstream High School Science Classroom

1. The above-named Individual Investigator has reviewed:
   b. the U.S. Department of Health and Human Services (HHS) regulations for the protection of human participants at 45 CFR part 46;
   c. the Federalwide Assurance (FWA) and applicable Terms of the FWA for the institution referenced above; and
   d. the relevant institutional policies and procedures for the protection of human participants.

2. The Investigator understands and hereby accepts the responsibility to comply with the standards and requirements stipulated in the above documents and to protect the rights and welfare of human participants involved in research conducted under this Agreement.

3. The Investigator will comply with all other applicable federal, international, state, and local laws, regulations, and policies that may provide additional protection for human participants participating in research conducted under this agreement.

4. The Investigator will abide by all determinations of the Institutional Review Board (IRB) designated under the above FWA and will accept the final authority and decisions of the IRB, including but not limited to directives to terminate participation in designated research activities.

5. The Investigator will complete any educational training required by the Institution and/or the IRB prior to initiating research covered under this Agreement.

6. The Investigator will report promptly to the IRB any proposed changes in the research conducted under this Agreement. The investigator will not initiate changes in the research without prior IRB review and approval, except where necessary to eliminate apparent immediate hazards to participants.

7. The Investigator will report immediately to the IRB any unanticipated problems involving risks to participants or others in research covered under this Agreement.

8. The Investigator, when responsible for enrolling participants, will obtain, document, and maintain records of informed consent for each such participant or each participant’s legally authorized representative as required under HHS regulations at 45 CFR part 46 and stipulated by the IRB.

9. The Investigator acknowledges and agrees to cooperate in the IRB’s responsibility for initial and continuing review, record keeping, reporting, and certification for the research referenced above. The Investigator will provide all information requested by the IRB in a timely fashion.
10. The Investigator will not enroll participants in research under this Agreement prior to its review and approval by the IRB.

11. Emergency medical care may be delivered without IRB review and approval to the extent permitted under applicable federal regulations and state law.

12. This Agreement does not preclude the Investigator from taking part in research not covered by this Agreement.

13. The Investigator acknowledges that he/she is primarily responsible for safeguarding the rights and welfare of each research participant, and that the participant’s rights and welfare must take precedence over the goals and requirements of the research.

**Investigator Signature**: ______________________________________________________

Date ______________

Name: ___________________________________________________________________

( _Last_ ) ( _First_ ) ( _Middle Initial_ )

Degree(s): ________________

Address: __________________________________________________________________

_________________________________________________________________

( _City_ ) ( _State/Province_ ) ( _Zip/Country_ )

Phone #: ______________

**FWA Institutional Official (or Designee)**: Signatory authority granted by Dr. Eva J. Pell, Senior Vice President for Research & Institutional Official, to Ms. Yekel to sign as proxy – via memo dated September 14, 2007.

Signature: __________________________________________ Date: ________________

Name: Candice A. Yekel, MS, CIM

Institutional Title: Director, Office for Research Protections

Address: 201 Kern Graduate Building
University Park, PA 16802

Telephone #: 814-865-1775
Vita
Cary Alan Supalo

EDUCATION
Ph.D. in Chemistry, emphasis in chemical education, 2010, Pennsylvania State University
M.S. in Chemistry, emphasis in catalysis, 2005, Pennsylvania State University
B.S. in Chemistry, B.A. in Communications, 1999, Purdue University

RESEARCH
Project Manager, Independent Laboratory Access for the Blind (ILAB), 2004-2010, Pennsylvania State University (under research adviser Thomas E. Mallouk)
Graduate Research Assistant, problems in inorganic heterogeneous catalysis, 2000-2004, Pennsylvania State University (under research adviser Thomas E. Mallouk)
Research Assistant, problems in inorganic heterogeneous catalysis, 2000, Universal Oil Products, Des Plaines, IL (under Dr. Richard R. Willis of Universal Oil Products)

TEACHING
Instructor, Chemistry 101 Academic Summer Enrichment, 2010, Pennsylvania State University

SELECTED PUBLICATIONS (of total 12 to date)

SELECTED PROFESSIONAL ACTIVITIES
Visiting Scholar, Purdue University with Dr. George M. Bodner, professor of chemical education, 2008-current
Invited Lecturer, Multi-Sensory Approaches to Teaching Chemistry to Students with Blindness or Low Vision, Princeton University, 2010
Co-Organizer, Multi-Sensory Science Educators Conference, University of Wisconsin, 2009
Symposium Chair, Multi-Sensory Learning Experiences for Special Needs Learners in the Chemistry Classroom, Biennial Conference on Chemical Education, 2008, 2010
Chemistry Curriculum Coordinator/Instructor, National Federation of the Blind’s Youth Slam summer program for high school students, 2007, 2009
Workshop Coordinator, Seeing Chemical Reactions through Sound, Republic of Trinidad & Tobago, 2009
Invited Lecturer, Tools for Teachers: Accessibility in the Science Lab for Blind Students, College of New Jersey, 2008
Co-Chair, ILAB Conference, University of Wisconsin, 2008
Coordinator, ILAB Open House, Pennsylvania State University, 2006, 2007