Portable Technologies
Science Learning in Context
INNOVATIONS IN SCIENCE EDUCATION AND TECHNOLOGY

Series Editor:
Karen C. Cohen, Harvard University, Cambridge, Massachusetts

Are Schools Really Like This?: Factors Affecting Teacher Attitude toward School Improvement
J. Gary Lilyquist

Education for a Sustainable Future: A Paradigm of Hope for the 21st Century
Edited by Keith A. Wheeler and Anne Perraca Bijur

The Hidden Curriculum—Faculty-Made Tests in Science
Part 1: Lower-Division Courses
Part 2: Upper-Division Courses
Sheila Tobias and Jacqueline Raphael

Internet Links for Science Education: Student–Scientist Partnerships
Edited by Karen C. Cohen

Place of Science in a World of Values and Facts
Loucas G. Christophorou

Portable Technologies: Science Learning in Context
Edited by Robert F. Tinker and Joseph S. Krajcik

Science, Technology, and Society: A Sourcebook on Research and Practice
Edited by David D. Kumar and Daryl E. Chubin

Technology, Science Teaching, and Literacy: A Century of Growth
Kenneth P. King

Time for Science Education
Michael R. Matthews

Tutorial Distance Learning: Rebuilding Our Educational System
Alfred Bork and Sigrun Gunnarsdottir

David W. Brooks, Diane E. Nolan, and Susan M. Gallagher

A Continuation Order Plan is available for this series. A continuation order will bring delivery of each new volume immediately upon publication. Volumes are billed only upon actual shipment. For further information please contact the publisher.
Portable Technologies
Science Learning in Context

Edited by
Robert F. Tinker
The Concord Consortium
Concord, Massachusetts

Joseph S. Krajcik
University of Michigan
Ann Arbor, Michigan

SPRINGER SCIENCE+BUSINESS MEDIA, LLC
Preface

This is a book about how portable information technologies can transform education. Rather than merely speculate about these issues, we have implemented a portion of the future in real classrooms, and taken a careful look at the resulting teaching and learning. Our research suggests that in the near future small, handheld computers could become, for all students, a powerful and inexpensive tool for investigating and learning.

ACKNOWLEDGEMENTS

We have been able to undertake this peek into the future as a result of a generous three-year grant from the National Science Foundation's Applications of Advanced Technology program in collaboration with colleagues at the University of Michigan, the Global River Environmental Education Network,\(^1\) and Apple Computer, Inc. The research we report in this book and speculations about its implications was part of the Science Learning in Context (SLiC) project.

COLLABORATORS

This research was conducted under my direction at the Concord Consortium in collaboration with a dedicated group of organizations and

\(^1\) In 1999 GREEN (Global River Environmental Education Network) merged with Earth Force, Inc.
people. One collaboration was in the form of a subgrant to the University of Michigan under the direction of Elliot Soloway. A second subgrant was made to GREEN under Keith Wheeler’s direction. Essential to our study was the dedicated work of teachers David Tucker at Mount Baker High School and Ann Novak and Chris Gleason at Greenhills Middle School, all of whom taught fearlessly the new material using unfamiliar “bleeding edge” technology.

The Concord Consortium’s Director of Technology, Stephen Bannasch, designed most of the original hardware and software. As the Project Manager, Kathryn Costello kept the project organized and on budget. Carolyn Staudt developed the curriculum materials that were released with eProbe. Walter Lenk developed and built much of the electronics. Noah Fields developed Internet and information services. Johan van der Hoeven wrote software for portable computers to interface with commercial datalogger devices. Jorge Trench helped develop new instrumentation, including colorimeter and photometer probes. Dick Walton helped with teacher training and produced the video of our summer science workshops in 1996. Bonnie Elbaum assisted with the development of the curriculum and the construction and testing of the photometer and colorimeter probes.

At the University of Michigan, Joseph Krajcik supervised the classroom research and its analysis with assistance from Mary Starr. Undergraduates Dawn Banka and Benjamin Zum Brunnen helped develop the eProbe software. Graduate student Mike Bailey contributed to the software and analyzed the available wireless technologies.

Lisa Bryce Lewis of GREEN was our liaison in the Northwest and contributed to the curriculum materials. Peter Kelley and Kathryn Mitchell videotaped classrooms and recorded data on student learning at Mount Baker High School. Mike Appel, in GREEN’s Michigan office, videotaped classes and recorded data on student participation and learning in Greenhills.

We are indebted to Dr. Wayne Grant for serving as a special project advisor and for first bringing the idea of ubiquitous, wireless, portable computing to our attention and to the world, through his movies *The Wireless Coyote* and *Rain Forest Classroom*. Our technology was published under the eProbe label by the Knowledge Revolution under Wayne Grant’s direction, with major contributions from Julie Scherer, who managed the development of eProbe, and Rhonda Rosales. When eProbe was terminated, Wayne started ImagiWorks, where he developed and marketed equivalent probeware for the Palm and Visor computers. Marcus Darden was responsible for implementing the eProbe software on the Newton platform, first as a graduate student at the University of Michigan and later at Knowledge Revolution.

The manuscript of this book has gone through several iterations.
Kathryn Costello and Lee McDavid have provided invaluable assistance getting this book to press.

The good ideas and findings reported in this volume are completely dependent on these colleagues, whereas any errors, omissions, or inaccuracies are my responsibility. The opinions and findings of this report are those of the authors and do not reflect the views of their institutions or those of the National Science Foundation.

Robert F. Tinker
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>v</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Chapter 1: Supporting Science Learning in Context: Project-Based Learning</td>
<td>7</td>
</tr>
<tr>
<td>Chapter 2: Incorporating Portable Technology to Enhance an Inquiry, Project-Based Middle School Science Classroom</td>
<td>29</td>
</tr>
<tr>
<td>Chapter 3: Case Study at Mount Baker High School</td>
<td>63</td>
</tr>
<tr>
<td>Chapter 4: Curriculum Design Principles for Using Probeware in a Project-Based Learning Setting: Learning Science in Context</td>
<td>87</td>
</tr>
<tr>
<td>Chapter 5: Learning Science Content in a Project-based Environment</td>
<td>103</td>
</tr>
<tr>
<td>Chapter 6: Educational Innovations in Portable Technologies</td>
<td>121</td>
</tr>
<tr>
<td>Conclusion</td>
<td>147</td>
</tr>
<tr>
<td>Appendix A: Chapter 2</td>
<td>167</td>
</tr>
<tr>
<td>Appendix B: Chapter 4</td>
<td>175</td>
</tr>
<tr>
<td>Appendix C: Chapter 5</td>
<td>181</td>
</tr>
<tr>
<td>Index:</td>
<td>191</td>
</tr>
</tbody>
</table>