

VISUALIZATION: THEORY AND PRACTICE
IN SCIENCE EDUCATION

Models and Modeling in Science Education

Volume 3

Series Editor

Professor J.K. Gilbert
Institute of Education, The University of Reading, UK

Editorial Board

Professor D.F. Treagust
Science and Mathematics Education Centre, Curtin University of Technology,
Australia

Assoc. Professor J.H. van Driel
ICLON, University of Leiden, The Netherlands

Dr. Rosária Justi
Department of Chemistry, University of Minas Gerais, Brazil

Dr. Janice Gobert
The Concord Consortium, USA

For other titles published in this series, go to
http://www.springer.com/springer_series_in_computer_science

Visualization: Theory and Practice in Science Education

John K. Gilbert

Editor

The University of Reading, UK

Miriam Reiner

Editor

Technion, Israel Institute of Technology, Israel

Mary Nakhleh

Editor

Purdue University, USA

 Springer

Editors

John K. Gilbert
The University of Reading,
UK

Miriam Reiner
Technion, Israel Institute of Technology,
Israel

Mary Nakhleh
Purdue University,
USA

ISBN: 978-1-4020-5266-8

e-ISBN: 978-1-4020-5267-5

Library of Congress Control Number: 2007936483

© 2008 Springer Science+Business Media B.V.

No part of this work may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, microfilming, recording or otherwise, without written permission from the Publisher, with the exception of any material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work.

Printed on acid-free paper.

9 8 7 6 5 4 3 2 1

springer.com

Contents

Introduction	1
John K. Gilbert, Miriam Reiner and Mary Nakhleh	
1 Visualization: An Emergent Field of Practice and Enquiry in Science Education	3
John K. Gilbert	
Section A The Nature and Development of Visualization: A Review of what is Known	25
Miriam Reiner	
2 The ‘Ins’ and ‘Outs’ of Learning: Internal Representations and External Visualizations	29
David N. Rapp and Christopher A. Kurby	
3 Comprehending and Learning from ‘Visualizations’: A Developmental Perspective	53
David H. Uttal and Katherine O’ Doherty	
4 Seeing Through Touch: The Role of Haptic Information in Visualization	73
Miriam Reiner	
Section B The Design of Units and Courses Focused on Visualization	85
Mary Nakhleh	
5 Using External Visualizations to Extend and Integrate Learning in Mobile and Classroom Settings	89
Yvonne Rogers	
6 Visualizing the Molecular World – Design, Evaluation, and Use of Animations	103
Roy Tasker and Rebecca Dalton	
7 Engineering Instructional Metaphors Within Virtual Environments to Enhance Visualization	133
Debbie Denise Reese	

8 Teaching Chemistry with and Without External Representations in Professional Environments with Limited Resources	155
Liliana Mammino	
Section C Learning with External Representations	187
John K. Gilbert	
9 The Educational Value of Multiple-representations when Learning Complex Scientific Concepts	191
Shaaron Ainsworth	
10 Learning Chemistry Using Multiple External Representations	209
Mary B. Nakhleh and Brian Postek	
11 Representational Resources for Constructing Shared Understandings in the High School Chemistry Classroom	233
Vera Michalchik, Anders Rosenquist, Robert Kozma, Patty Kreikemeier and Patricia Schank	
12 Visualization Without Vision: Students with Visual Impairment	283
M. Gail Jones and Bethany Broadwell	
13 When an Image Turns into Knowledge: The Role of Visualization in Thought Experimentation	295
Miriam Reiner and John Gilbert	
About the Authors	311
Subject Index	317
Author Index	319

Contributors

Shaaron Ainsworth University of
Nottingham, UK
Shaaron.Ainsworth@nottingham.
ac.uk

Bethany Broadwell
North Carolina State University, USA
Bethany.Broadwell@ncsu.edu

Brian Coppola
University of Michigan, USA
bcoppola@umich.edu

Rebecca Dalton
University of Western Sydney, Australia
R.Dalton@uws.edu.au

John K. Gilbert
The University of Reading, UK
j.k.gilbert@reading.ac.uk

M. Gail Jones
North Carolina State University, USA
Gail_Jones@ncsu.edu

Robert Kozma
SRI International, USA
Robert.Kozma@sri.com

Patty Kreikemeier
Lawrence Hall of Science, UC Berkeley
USA
patty@berkeley.edu

Christopher A. Kurby
University of Memphis, USA
ckurby@mail.psy.memphis.edu

Liliana Mammino
University of Venda,
Republic of South Africa
sasdestria@yahoo.com

Vera Michalchik
SRI International, USA
Vera.michalchik@sri.com

Mary B. Nakhleh
Purdue University, USA
mnakhleh@purdue.edu

Katherine O' Doherty
Northwestern University, USA
k-odoherty@northwestern.edu

Brian Postek
Purdue University, USA
bpostek@purdue.edu

David N. Rapp
Northwestern University, USA,
rapp@northwestern.edu
rapp@northwestern.edu

Debbie Denise Reese
Wheeling Jesuit University, USA
Debbie@cet.edu

Miriam Reiner

Technion, Israel

miriamr@technion.ac.il

Yvonne Rogers

Open University, UK

y.rogers@open.ac.uk

Anders Rosenquist

SRI International, USA

Andersr@stanfordalumni.org

Patricia Schank

SRI International, USA

Patricia.schank@sri.com

Roy Tasker

University of Western Sydney, Australia

r.tasker@uws.edu.au

David H. Uttal

Northwestern University, USA,

duttal@Northwestern.edu

duttal@northwestern.edu

Introduction

John K. Gilbert, Miriam Reiner and Mary Nakhleh

Interest in the educational value of material objects, pictures, diagrams, tables, graphs and the like, in science education has increased greatly in recent years (Gilbert, 2005). This has been facilitated to a large extent by the exponential rise in the memory capacity of personal computers and to the associated investment made in software development, which have combined to enable major innovations in instructional techniques to take place. For any educational innovation to succeed – to be widely adopted and persistently practiced – three associated aspects of any pedagogic innovation have to be initially addressed. Practical, user-friendly, examples of the innovation must be developed, tried out in classrooms, and their use evaluated. The contribution of the innovation to the curriculum must be explored – an identification of where the innovation may be used either to improve existing educational practice or to provide new forms of instruction. Why an innovation is successful – why it makes a worthwhile contribution to learning – must be established. These three aspects are inter-related and should be mutually reinforcing. The biggest issue of all – the provision of widespread and effective opportunities for teacher ‘continuing professional development’ in respect of the innovation – must be addressed from the outset.

The problem in many such cases, and certainly the case here, is that each one of these aspects is taken as a focus for work by a different academic community. The development of practical examples of such innovations is undertaken by the science community, often primarily interested in their use within scientific research and perhaps secondarily in their use in the training of future scientists. The curricular contribution of these innovations and opportunities for continuing professional development receives the attention of the science education community. The nature of their contribution to learning is seen as the province of the cognitive science community. The success of this type of innovation is hindered because these communities are not in any systematic direct contact with each other. We believe that one of the strengths of this book is that it brings together a collection of papers that contain the theoretical perspectives, understandings, and frameworks of several of

John K. Gilbert
Institute of Education, The University of Reading, UK

these communities. We hope that this book can serve as the beginnings of a bridge between these diverse communities.

However, a lack of communication means that the drawing together of the contributions to the field by authors from diverse academic backgrounds will be hindered by their use of different specialist terminologies. Key words may be used in different ways, yet a commonality of meaning must be established if insights are to be synthesised and new perspectives opened up. There are two generic systems in use in this area of innovation. In Convention 1, a representation is the depiction of anything; an external representation is one that has been placed in the public realm, in either a material object, visual, verbal, or symbolic form; an internal representation is one that is constructed mentally by an individual; a visualization is the understanding of, the meaning attributed to, an internal representation. In Convention 2, a visualisation is a representation that has been placed in the public realm in either material object, visual, verbal, or symbolic form; the mental representation produced by an individual from a visualization is an image. The difference between the two Conventions lies in the meaning of the word visualization: in Convention 1 it is a verb (to visualize something is to mentally act on it); in Convention 2 it is a noun (a visualization is something that is in the public realm). There are, inevitably, phrases that cut across the two conventions: 'visual representation', 'visuo-spatial thinking', 'representational insights'.

We have brought together the chapters of this book to promote the formation of links between those concerned respectively with theory, curriculum place, and pedagogic practice. In writing for and editing for it, we have decided to adopt Convention 1, for we wish to place the emphasis on the nature of the mental actions undertaken by individuals in using representations. Some of the contributing authors have adopted Convention 2. In order to avoid confusing the reader, where the word visualization is used in the Convention 2 sense, we have entered it as 'visualization', leaving the use of the word without parenthesis to be the meaning in Convention 1.

The book is divided into three Sections, dealing respectively with the first three aspects of innovation in respect of external representation, internal representation, and visualization.

Reference

Gilbert, J. K. (Ed.). (2005). *Visualization in science education*. Dordrecht: Springer.