THE CAMBRIDGE HANDBOOK OF MULTIMEDIA LEARNING

Third Edition

Digital and online learning is more prevalent than ever, making multimedia learning a primary objective for many instructors. *The Cambridge Handbook of Multimedia Learning* examines cutting-edge research to guide creative teaching methods in online classrooms and training. Recognized as the field's major reference work, this research-based handbook helps define and shape this area of study. This third edition provides the latest progress report from the world's leading multimedia researchers, with 46 chapters on how to help people learn from words and pictures, particularly in computer-based environments. The chapters demonstrate what works best and establishes optimized practices. It systematically examines well-researched principles of effective multimedia instruction and pinpoints exactly why certain practices succeed by isolating the boundary conditions. The volume is founded upon research findings in learning theory, giving it an informed perspective in explaining precisely how effective teaching practices achieve their goals or fail to engage.

RICHARD E. MAYER is Distinguished Professor of Psychological and Brain Sciences at the University of California, Santa Barbara, USA. He served as President of Division 15 (Educational Psychology) of the American Psychological Association and Vice President of the American Educational Research Association for Division C (Learning and Instruction).

LOGAN FIORELLA is Associate Professor of Educational Psychology at the University of Georgia, USA. He is a National Academy of Education/Spencer postdoctoral fellow and a fellow of the Psychonomic Society. He has also served as Principal Investigator or Co-Principal Investigator on grants from the National Science Foundation, the Institute of Education Sciences, and the Spencer Foundation.

THIRD EDITION

THE CAMBRIDGE HANDBOOK OF MULTIMEDIA LEARNING

Edited by

Richard E. Mayer

University of California, Santa Barbara

Logan Fiorella

University of Georgia

CAMBRIDGE UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre,
New Delhi – 110025, India

103 Penang Road, #05–06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781108841580
DOI: 10.1017/9781108894333

First published 2022

Printed in the United Kingdom by TJ Books Limited, Padstow Cornwall

A catalogue record for this publication is available from the British Library.

Library of Congress Cataloging-in-Publication Data
Names: Mayer, Richard E., 1947- editor. | Fiorella, Logan, editor.
Title: The Cambridge handbook of multimedia learning / edited by Richard E. Mayer, University of California, Santa Barbara, Logan Fiorella, University of Georgia.
Description: Third Edition. | New York, NY : Cambridge University Press, 2022. | Series: Cambridge handbooks in psychology | Revised edition of The Cambridge handbook of multimedia learning, 2014. | Includes bibliographical references and index.
Identifiers: LCCN 2021026035 (print) | LCCN 2021026036 (ebook) | ISBN 9781108841580 (hardback) | ISBN 9781108814669 (paperback) | ISBN 9781108894333 (epub)
Subjects: LCSH: Computer-assisted instruction. | Interactive multimedia. | BISAC: PSYCHOLOGY / General | PSYCHOLOGY / General
Classification: LCC LB1028.5 .C283 2022 (print) | LCC LB1028.5 (ebook) | DDC 371.33/4–dc23
LC record available at https://lccn.loc.gov/2021026035
LC ebook record available at https://lccn.loc.gov/2021026036

ISBN 978-1-108-84158-0 Hardback
ISBN 978-1-108-81466-9 Paperback

Contents

Figures

Tables

Contributors

Olusola O. Adesope *Washington State University, USA*
Shirley Agostinho *University of Wollongong, Australia*
Shaaron Ainsworth *University of Nottingham, UK*
Vincent Aleven *Carnegie Mellon University, USA*
Paul Ayres *University of New South Wales, Australia*
Roger Azevedo *University of Central Florida, USA*
Jean-Michel Boucheix *University of Burgundy, France*
Anne Britt *Northern Illinois University, USA*
Gino Camp *Open University of the Netherlands, The Netherlands*
Juan Cristobal Castro-Alonso *University of Chile, Chile*
Paul Chandler *University of Wollongong, Australia*
Michelene T. H. Chi *Arizona State University, USA*
Richard E. Clark *University of Southern California, USA*
Ruth Colvin Clark *Clark Training & Consulting, USA*
Daryn Dever *University of Central Florida, USA*
David F. Feldon *Utah State University, USA*
Logan Fiorella *University of Georgia, USA*
Chris Hovey *New York University, USA*
Jeroen Janssen *Utrecht University, The Netherlands*
Halszka Jarodzka *Open University of the Netherlands, The Netherlands*
Soojeong Jeong *Utah State University, USA*
Dayu Jiang *Wuhan University, China*
Cheryl I. Johnson *Naval Air Warfare Center Training Systems Division, USA*
Ton de Jong *University of Twente, The Netherlands*
Slava Kalyuga *University of New South Wales, Australia*
Liesbeth L. Kester *Utrecht University, The Netherlands*
Femke Kirschner *Utrecht University, The Netherlands*
Paul A. Kirschner *Open University of the Netherlands, The Netherlands and Thomas More University of Applied Sciences, Belgium*
Kenneth Koedinger *Carnegie Mellon University, USA*
Bjorn de Koning *Erasmus University Rotterdam, The Netherlands*
Susanne P. Lajoie *McGill University, Canada*
Claudia Leopold *University of Fribourg, Switzerland*
Detlev Leutner *University of Duisburg-Essen, Germany*
Wenjing Li *Tianjin Normal University, China*
Marlit Annalena Lindner *IPN – Leibniz Institute for Science and Mathematics Education, Germany*
Richard K. Lowe *Curtin University, Australia and University of Burgundy, France*
Guido Makransky *University of Copenhagen, Denmark*
Matthew D. Marraffino *Naval Air Warfare Center Training Systems Division, USA*
Richard E. Mayer *University of California, Santa Barbara, USA*

Matthew T. McCrudden *Pennsylvania State University, USA*
John C. Nesbit *Simon Fraser University, Canada*
Fred Paas *Erasmus University Rotterdam, The Netherlands and University of Wollongong, Australia*
Jocelyn Parong *University of Wisconsin, USA*
Jan L. Plass *New York University, USA*
Alexander Renkl *University of Freiburg, Germany*
Jean-François Rouet *French National Center for Scientific Research, France and University of Poitiers, France*
Katharina Scheiter *Leibniz-Institut fur Wissenmedien, Germany*
Annett Schmeck *Ruhr University of Bochum, Germany*
Wolfgang Schnotz *University of Koblenz-Landau, Germany*
Claudia Schrader *University of Wuppertal, Germany*
NarayanKripa Sundararajan *Independent Researcher, USA*
Tim Surma *Thomas More University of Applied Sciences, Belgium*
John Sweller *University of New South Wales, Australia*
Sharon Tindall-Ford *University of Wollongong, Australia*
Tamara van Gog *Utrecht University, The Netherlands*
Jeroen J. G. van Merriënboer *Maastricht University, The Netherlands*
Peggy N. Van Meter *Pennsylvania State University, USA*
Fuxing Wang *Central China Normal University, China*
Shirong Zhang *Erasmus University Rotterdam, The Netherlands*
Tingting Zhao *Central China Normal University, China*

Preface

As the first and only comprehensive research-based handbook on multimedia learning, *The Cambridge Handbook of Multimedia Learning* has helped define and shape the field, and has become recognized as its major reference work. Since the publication of the first edition in 2005 and the second edition in 2014, the field of multimedia learning has continued to grow as a coherent discipline with an accumulated research base worthy of being synthesized and organized in an updated handbook. Therefore, we are pleased to serve as editors for this third edition of *The Cambridge Handbook of Multimedia Learning*, which remains the most comprehensive and up-to-date volume summarizing research and theory in the field of multimedia learning.

This third edition of *The Cambridge Handbook of Multimedia Learning* constitutes the latest progress report from the world's leading multimedia researchers. As in previous editions, the focus of this volume is on how to help people learn from words and pictures, particularly in computer-based environments. For the purposes of the *Handbook*, multimedia learning is defined as learning from words (e.g., spoken or printed text) and pictures (e.g., illustrations, photos, maps, graphs, animation, or video). Multimedia environments include online instructional presentations, interactive lessons, e-courses, simulations, games, instructional video, virtual reality experiences, slideshows, and even textbooks. Overall, the major goal of this third edition of the *Handbook* is the same as the first edition – to establish what works (by systematically examining research-based principles of effective multimedia instruction), to pinpoint when it works (by isolating the boundary conditions), and to explain how it works (by grounding the research findings in learning theory). As noted in Chapter 1, compared to the first edition and second edition of the *Handbook*, this third edition reflects an increase in the number of evidence-based principles of multimedia instructional design, substantial growth in the research base underlying each principle, better understanding of the boundary conditions for each principle, broadening of underlying theories of multimedia learning, broadening of the media under study, increased interest in multimedia learning beyond the lab, and an increase in the arsenal of research tools.

There are many books providing advice on how to design multimedia learning environments, but the books are largely based on the practical experience and wisdom of the authors. Similarly, there are books reporting on the development of online instructional programs and websites, but the development efforts are generally based on best practices and informal case studies. Until recently, the lack of scientific research evidence in many multimedia learning books could be justified on the grounds that a solid research base did not yet exist. However, the quantity and quality of scientific research – conducted by researchers around the world – have reached a level warranting a revision of the field's first comprehensive research-based handbook of multimedia learning.

What distinguishes this book from some other books on distance learning or web-based instruction is our commitment to taking a scientific, evidence-based approach.

Our goal as editors is to make sure the *Handbook* provides a comprehensive and focused overview of the state of scientific research on multimedia learning. Each chapter is based on empirical research and grounded in cognitive theory, rather than offering unsubstantiated recommendations, describing best practices, or summarizing software development accomplishments. The chapter authors are research leaders from around the world, who have records of research publication in multimedia learning. As the most comprehensive research-based handbook on multimedia learning, *The Cambridge Handbook of Multimedia Learning: Third Edition* is intended to continue to define and shape the field for years to come.

As editors, we asked leading multimedia researchers to author chapters in areas in which they have contributed to the empirical research base. Because the field is largely international, the chapter authors span the globe, with more than half the chapters written by authors outside the United States – including authors from Australia, Canada, Chile, China, Denmark, Germany, France, Switzerland, The Netherlands, and the United Kingdom.

The *Handbook* consists of 46 chapters organized into eight parts. These chapters provide background (in Part I), explain a foundational theory of multimedia learning (in Part II), focus on basic cross-cutting principles of multimedia learning (Part III), focus on principles of multimedia learning for reducing extraneous processing (Part IV) or for managing essential processing (Part V), focus on principles of multimedia learning based on social and affective features (Part VI) or generative activity (Part VII), or examine multimedia learning with various computer-based media (Part VIII).

In order to provide a common structure among the chapters of the *Handbook*, we asked authors to organize their chapters around a common set of issues. In particular, we asked the authors of the theory chapters to provide a concise description of the theory or model with concrete examples, to summarize the theory's contributions to cognitive theory (i.e., to specify predictions that have been tested), to summarize the theory's contributions to instructional design (i.e., to specify recommendations for instruction), to describe any limitations of the theory, and to suggest future directions for research. We asked the authors of the multimedia design chapters to provide a clear definition and example of the principle or topic of the chapter, to review the relevant published research literature in sufficient detail, to assess the limitations of the research base, to summarize the implications for cognitive theory and for instructional design, and to suggest directions for future research.

We solicited chapters that were concise (i.e., containing no more than 25 double-spaced pages), focused (i.e., reviewing the research on a specified topic), well-referenced (i.e., containing a rich set of relevant references), evidence-based (i.e., providing an up-to-date review of the best empirical evidence), theory-based (i.e., relating the findings to testable predictions of theories when appropriate), and educationally relevant (i.e., drawing implications for educational practice when appropriate). In order to minimize confusion, we asked authors to clearly define jargon terms in the text. Each chapter was subjected to peer review and revision.

The intended audience includes anyone interested in how people learn from words and pictures in computer-based environments (or with traditional print media or in face-to-face learning environments). Although the *Handbook* summarizes the research base in multimedia learning, it is intended to be accessible to a general audience. On one hand, the *Handbook* is designed to support readers with practical interests in how to design or select multimedia learning environments that promote learning. On the other hand, the *Handbook* is designed to support readers who have academic interests in conducting or evaluating research in multimedia learning. The *Handbook* would be appropriate for courses related to cognitive science, educational psychology, instructional design, human factors, multimedia arts and technology, professional training, and interface design. It would also be useful for instructors interested in designing or improving multimedia lessons in school settings, job training contexts, and informal environments. In short, *The Cambridge Handbook of Multimedia Learning: Third Edition* belongs on the bookshelf of anyone who is interested in taking an evidence-based approach to web-based learning, e-learning,

multimedia, website design, distance learning, instructional technology, human–computer interaction, virtual environments, interactive instructional environments, or applied cognitive psychology.

As editors, we have tried to ensure that the *Handbook* reflects the values that we think are important for our field. In particular, we sought to produce a *Handbook* that is:

Research-based: The *Handbook* is intended to summarize the empirical research on multimedia learning, rather than describe untested best practices or software development projects. Although we have much respect for the craft knowledge of practitioners and designers, it is important to know if recommendations are supported by scientific evidence and under what conditions they are supported. Thus, we value a focus on scientific evidence as the key to progress in our field.

Theory-grounded: The *Handbook* is intended to relate empirical research to cognitive theories of how people learn. Our overriding premise is that multimedia learning environments should be designed in ways that are consistent with what is known about how people learn.

Educationally-relevant: The *Handbook* focuses on issues that are relevant to education, that is, to helping people learn. Thus, we sought chapters that offer research-based implications for instructional design.

Comprehensive: The *Handbook* offers a broad view of the field, including contributions from multimedia researchers around the world. We value the perspectives of researchers who have devoted so much of their energy to understanding multimedia learning.

Timely: The *Handbook* offers an up-to-date overview of the field. We value timeliness because the scientific study of multimedia learning is maturing at a rapid pace, and so are the practical demands for building multimedia learning environments – ranging from e-courses to in-class simulations.

Readable: In our role as editors we have tried to make sure that the chapters are clear and concise, with key terms defined and concrete examples provided. In a multidisciplinary field like this one, it is important that the chapters communicate what is known in a way that general readers can appreciate.

In short, our values have motivated us to seek chapters that are based on empirical research and grounded in cognitive theory rather than chapters that mainly describe development efforts or best practices.

Editing this book has been a treat for us, because we could commission chapters from the best researchers in the field and be the first to learn what they had to say. We are pleased to share the fruits of this enterprise with you in a timely fashion. Our hope is that you enjoy reading this *Handbook* as much as we have enjoyed editing it. We will consider this *Handbook* to be a success if it helps you to understand what is known about how people learn from words and pictures, gives you useful help in building or selecting effective multimedia learning environments, or encourages you to produce or investigate research that contributes to cognitive theory and educational practice. We hope that you will feel free to contact us at mayer@ucsb.edu or lfiorella@uga.edu to share your comments about the *Handbook*.

Acknowledgments

Although our names are listed as the editors, this *Handbook* depended on the contributions of many people. In particular, we wish to thank the chapter authors for producing excellent chapters, for keeping this project on schedule, and for responding so well to the reviewer's comments. We also wish to thank David Repetto, Emily Watton, and the staff of Cambridge University Press for their many contributions to making this book a success.

From Richard E. Mayer: I am grateful to my many research collaborators who have worked with me over the years in the study of multimedia learning, including Deanne Adams, Richard B. Anderson, Robert Atkinson, Katie Bainbridge, Daphne Bavelier, Ben Bediou, Monica Bulger, Julie Campbell, Matt Canham, Paul Chandler, Dorothy Chun, Ruth Clark, Scott DaPra, Krista DeLeeuw, Gayle Dow, Logan Fiorella, Joan Gallini, Shawn Green, Shannon Harp, Mary Hegarty, Johannes Hellenbrand, Julie Heiser, Bruce Homer, Xiaoxia Huang, Nabil Issa, Kelsey James, Cheryl I. Johnson, Lewis Johnson, Alyssa Lawson, Hyunjeong Lee, Claudia Leopold, James Lester, Detlev Leutner, Lin Lin, Marlit Lindner, Steven Lonn, Andrew MacNamara, Guido Makransky, Patricia Mautone, Sarah Mayer, Bruce McLaren, Mike Miller, Roxana Moreno, Harold O'Neil, Maria Opfermann, Jocelyn Parong, Agnaldo Pedra, Alanna Peebles, Celeste Pilegard, Jan L. Plass, Hector Ponce, Annett Schmeck, Valerie Sims, Hiller Spires, Andy Stull, Eunmo Sung, Tamara van Gog, Fuxing Wang, Ning Wang, and Ashleigh Wells. I appreciate my home institution – the University of California, Santa Barbara – and numerous funding agencies – including the National Science Foundation, the Office of Naval Research, the US Department of Education, and the Andrew Mellon Foundation – who have supported my research on multimedia learning. Finally, my deepest appreciation goes to my wife, Beverly; my children, Ken, David, and Sarah; my grandchildren, Jacob, Avery, James, Emma, Caleb, Sophie, and Lily; my brothers, Bob and Bernie; and to the memory of my parents, James and Bernis Mayer.

From Logan Fiorella: I am grateful to my collaborators on research projects exploring multimedia learning, including Juan Cristobal Castro-Alonso, Bruce Homer, Vincent Hoogerheide, Shelbi Kuhlmann, Richard E. Mayer, Fred Paas, Jocelyn Parong, Celeste Pilegard, Jan L. Plass, Alexander Renkl, Andy Stull, Tamara van Gog, Jennifer Vogel-Walcutt, and Qian Zhang. I appreciate the support from my home institution – the University of Georgia – and the support from funding agencies, including the National Science Foundation and the Spencer Foundation. I am especially grateful to my wife, Deborah; my daughter Adina; and my parents, Nick and Sharon.