

# Contents

## Part I Theoretical Approaches to Models and Modeling

- 1 **Introducing a Framework for Modeling Competence.** . . . . . 3  
Annette Upmeier zu Belzen, Jan van Driel, and Dirk Krüger
- 2 **Semantic Views on Models: An Appraisal  
for Science Education** . . . . . 21  
Agustín Adúriz-Bravo
- 3 **A Framework for Modeling-Based Learning,  
Teaching, and Assessment** . . . . . 39  
Constantinos P. Constantinou, Christiana Th. Nicolaou,  
and Marios Papaevripidou
- 4 **Modeling Competence in the Light of Nature of Science** . . . . . 59  
Renee S. Schwartz

## Part II Assessing and Diagnosing Modeling Competence

- 5 **Illuminating Scientists' Modeling Competence** . . . . . 81  
Bev France
- 6 **Combining Visual and Verbal Data to Diagnose  
and Assess Modeling Competence.** . . . . . 99  
Inga Ubben, Sara L. Salisbury, and Kristy L. Daniel
- 7 **Assessing Modeling Competence with Questionnaires** . . . . . 117  
Sabrina Mathesius and Moritz Krell
- 8 **Drawing-Based Modeling in Teaching Elementary  
Biology as a Diagnostic Tool.** . . . . . 131  
Wouter R. van Joolingen, Juliette Schouten, and Frank Leenaars
- 9 **The Black Box Approach: Analyzing Modeling Strategies** . . . . . 147  
Moritz Krell and Susann Hergert

### **Part III Educating Teachers for Competence-Based Teaching of Models and Modeling**

- 10 Teachers' Views About Models and Modeling Competence Towards Developing Scientific Literacy in Young People . . . . .** 163  
Barbara A. Crawford and Kayla P. Flanagan
- 11 Using Epistemic Considerations in Teaching: Fostering Students' Meaningful Engagement in Scientific Modeling . . . . .** 181  
Li Ke and Christina V. Schwarz
- 12 A Responsive Methodological Construct for Supporting Learners' Developing Modeling Competence in Modeling-Based Learning Environments. . . . .** 201  
Todd Campbell, Thomas J. McKenna, Jihyun An, and Laura Rodriguez

### **Part IV Developing Students' Modeling Competence**

- 13 Learning to Play the Modeling Game . . . . .** 221  
Richard Lehrer and Leona Schauble
- 14 Toward an Epistemology of Modeling-Based Learning in Early Science Education . . . . .** 237  
Loucas T. Louca and Zacharias C. Zacharia
- 15 Supporting Primary Students' Developing Modeling Competence for Water Systems . . . . .** 257  
Cory T. Forbes, Kim Lange-Schubert, Florian Böschl, and Tina Vo
- 16 Designing Technology Environments to Support System Modeling Competence . . . . .** 275  
Tom Bielik, Lynn Stephens, Dan Damelin, and Joseph S. Krajcik
- 17 Learning Abstraction as a Modeling Competence. . . . .** 291  
Jonathan T. Shemwell and Daniel K. Capps

### **Part V Attainments and Challenges**

- 18 Attainments and Challenges for Research on Modeling Competence. . . . .** 311  
Jan van Driel, Dirk Krüger, and Annette Upmeier zu Belzen