

MATHEMATICAL MODELLING: A WAY OF LIFE

ICTMA 11



S J LAMON W A PARKER S K HOUSTON



ICTMA 11

**MATHEMATICAL MODELLING:
A WAY OF LIFE**

Omnia apud me mathematica fiunt.
With me everything turns into mathematics.

Rene Descartes

ABOUT THE EDITORS

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The Eleventh International Conference on the
Teaching of Mathematical Modelling and Applications

MATHEMATICAL MODELLING: A WAY OF LIFE

Edited by

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ICTMA PUBLICATIONS

- Berry JS, Burghes DN, Huntley ID, James DJG, Moscardini AO (1984) *Teaching and Applying Mathematical Modelling* Chichester: Ellis Horwood.
- Berry JS, Burghes DN, Huntley ID, James DJG, Moscardini AO (1986) *Mathematical Modelling Methodology, Models, and Micros* Chichester: Ellis Horwood.
- Berry JS, Burghes DN, Huntley ID, James DJG, Moscardini AO (1987) *Mathematical Modelling Courses* Chichester: Ellis Horwood.
- Blum W, Berry JS, Biehler R, Huntley ID, Kaiser-Messmer G, Profke L (1989) *Applications and Modelling in Learning and Teaching Mathematics* Chichester: Ellis Horwood.
- Niss M, Blum W, Huntley ID (1991) *Teaching of Mathematical Modelling and Applications* Chichester: Ellis Horwood.
- de Lange J, Keitel C, Huntley ID, Niss M (1993) *Innovation in Maths Education by Modelling and Applications* Chichester: Ellis Horwood.
- Sloyer C, Blum W, Huntley ID (1995) *Advances and Perspectives in the Teaching of Mathematical Modelling and Applications* Yorklyn Delaware: Water Street Mathematics.
- Houston SK, Blum W, Huntley ID, Neill NT (1997) *Teaching and Learning Mathematical Modelling* Chichester: Albion Publishing Ltd. (now Horwood Publishing Ltd.).
- Galbraith P, Blum W, Booker G, Huntley ID (1998) *Mathematical Modelling, Teaching, and Assessment in a Technology-Rich World* Chichester: Horwood Publishing Ltd.
- Matos JF, Blum W, Houston SK, Carreira SP (2001) *Modelling and Mathematics Education ICTMA 9: Applications in Science and Technology* Chichester: Horwood Publishing Ltd.
- Ye Q, Blum W, Houston SK, Jiang Q (2003) *Mathematical Modelling in Education and Culture: ICTMA 10* Chichester: Horwood Publishing Ltd.
- Lamon SJ, Parker WA, Houston SK (2003) *Mathematical Modelling: A Way of Life: ICTMA 11* Chichester: Horwood Publishing Ltd.

PREFACE

Mathematical Modelling: A Way of Life

Those who teach mathematical modelling at the university level and those who use it to solve problems in a wide variety of disciplines, speak of mathematical modelling as a “way of life.” This phrase refers to their worldview, their habits of mind, and their dependence on the power of mathematics to describe, explain, predict, and control real phenomena. The expression suggests that mathematics is indispensable as a way of knowing about the world in which they live and about the complex phenomena that affect the quality of their lives. Everything turns into mathematics.

The great difficulty that students face when they study mathematical modelling at the university suggests that it is nearly impossible to adopt this new way of looking at the world so late in one’s education. Without any prior experience in building, interpreting and applying mathematical models, it is difficult to imagine that some students will ever see modelling as a “way of life.” It is clearly not enough that students go through the motions of educating themselves by accumulating and remembering a storehouse of unconnected bits and facts. If students do not develop the spirit of scientific investigation—longing to know and to understand, questioning all sorts phenomena, conducting logical and systematic investigations, considering premises, and predicting and explaining consequences—they must be helplessly obedient to emotions, pressures, influences, and the authority of other people. At best, they will be reactive and defensive in the face of every problem or crisis that occurs.

Accordingly, one of the chief goals of ICTMA 11 is to explore the ways in which teachers at all levels of schooling may provide opportunities for their students to model a variety of real phenomena in ways that are appropriately matched to the students’ mathematical backgrounds and interests. Conference participants were invited to examine from a variety of perspectives what it means to move beyond the efficient transmission of content in the mathematics classroom, toward creating a classroom atmosphere that conveys critical values, shapes useful processes, and rewards powerful thinking. This volume contains 23 contributions to ICTMA 11, many of which address the problems of helping school students to adopt mathematical modeling as a way of life.

ICTMA 11 has the distinction of marking at least two “firsts.” As we write this preface, it is three months before conference convenes in Milwaukee, Wisconsin, USA. The presenters/authors and the editors have worked intensively during the year preceding the conference to prepare manuscripts so that conference participants can receive this book when they arrive in Milwaukee. In part, this effort is a response to the ever-lengthening time period between the end of a conference and the book’s publication—in some cases, almost two years. We suspect that looking ahead after the conference may be more motivating and productive than looking back. We hope that the extensive review, feedback, and revision process that has already taken place will make for interesting and

well-prepared presentations at the conference, and that discussion of these papers in Milwaukee will stimulate ideas and fuel follow-up studies well in advance of the ICTMA 12 meeting in London.

Unfortunately, ICTMA 11 is also the first of our conferences for which participants have had to make travel plans during wartime. Because of the war in Iraq, the SARS epidemic, and the resulting difficulties with the airline companies, conference registrations are considerably lower than ever before and we are very grateful to our publisher, Ellis Horwood of Horwood Publishing, for producing a paperback book. We appreciate not only his willingness to provide this war-time edition, but the consistent support he has shown ICTMA for the last twenty years.

We are grateful to all of the reviewers who freely gave of their time and talents to help the authors and the editors prepare manuscripts for publication. We express our gratitude to Mrs. Pamela Entriakin for her hard work in organizing ICTMA 11, to Marquette University for hosting the conference, and to our friends and corporate sponsors.

Sue Lamon, Bill Parker, and Ken Houston

Section A

Modelling in the Elementary School

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Mathematical Modelling With Young Learners

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Current research is demonstrating that young children can make significant mathematical and social gains from working authentic modelling problems. This paper argues for the implementation of mathematical modelling activities within the elementary and middle school years. The key features of these activities that make them rich learning experiences for children are explored. Some detailed analyses of how children develop and apply generalizable conceptual systems are then presented. It is argued that analogical and case-based reasoning processes play a powerful role in the construction and application of generalized models.

I wish to thank Helen Doerr for her valuable feedback on an earlier version of this article. The assistance provided by Dr. Kathy Charles and Katrina Lewis during data collection is also gratefully acknowledged. This research is supported by a grant from the Australian Research Council.