Book Review

Researching, teaching and the practice of mathematical modelling and applications

Gloria Stillman

Christopher Haines, Peter Galbraith, Werner Blum, and Sanowar Khan (Eds.) (2007), *Modelling ICTMA12: Education, Engineering and Economics*. Chichester, UK: Horwood Publishing. ISBN-13: 978-1-904275-20-6

This is the thirteenth volume in the ICTMA series of books which emanate from the series of biennial International Conferences on the Teaching of Mathematical Modelling and Applications. The book contains 49 chapters by authors from a wide cross-section of countries including three chapters by Nordic authors. The theme of the conference was *Model transitions in the real world: research, teaching, practice*. In his preface to the book, Haines points out "The effective practice, teaching and learning of mathematical modelling and applications play major roles in enabling successful activity within industry, business and commerce, and education. Mathematical modelling permeates society and so it is very appropriate that ICTMA contributions cover the whole spectrum of mathematicians, engineers and scientists, modellers in industry, government and finance, and teachers and researchers in schools and universities" (p. v). Models, modelling and applications for education, business and the professions featured strongly in the conference academic programme and this is reflected in the seven sections of the book.

The first two sections comprise the plenaries from the conference. In the first of these, *Models and modelling in reality*, Julian Hunt FRS gives a

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Stillman, G. (2007). *Researching, teaching and the practice of mathematical modelling and applications*. Nordic Studies in Mathematics Education, 12 (4), 73–78.

comprehensive overview of some of the major themes faced by modellers in applied mathematics today such as predictability, accuracy, patterns in systems behaviour and voluminous amounts of data; whilst Kate Barker, a member of the monetary policy committee of the Bank of England, discusses the range of issues that arise from the use of economic models and the importance of recognising the context when selling particular models to the bank's clients. The second section is entitled, *Modelling constructs in education*, and focusses on primary and secondary schooling. Here, Galbraith points out that there are yet "more windmills to conquer" in the area of mathematical modelling and applications to the real world taking a stronghold in classrooms but we can dream a "possible dream". In response to a perceived "need for frameworks to guide and test the development of theoretically consistent approaches to teaching and learning", he suggests using Valsiner's zone theory (Valsiner, 1997) as such a theoretical frame in order to "conceptualise the structure and impact of person-environment relationships" (p. 58). He then proceeds to apply this system of zones (i.e., ZPA, the *zone of promoted action*; ZPD, an extended version of Vygotsky's *zone of proximal development*; and the ZFM, the *zone of free movement*) to "the construction and analysis of teaching to achieve modelling goals" (p. 58) in primary and secondary schooling. He identifies several "dialectic tensions between the needs of a modelling program that prioritises real-world activity, and a classroom providing a conservative approach to mathematics teaching" (p. 60). Galbraith then argues that "the existence of particular educational requirements, customs or classsroom procedures can be identified as potential blockages to the implementation of a modelling pedagogy" (p. 60). Maaß adds to previous attempts to flesh out the concept of "modelling competencies" by providing readers a window into what students (age 13–14 years old) in her research classrooms learnt from engaging in modelling. Hoyles and Noss report on the design of a programming environment for students to build models of their mathematical and scientific knowledge and a set of web-based collaboration tools to share ideas and programmed models. It was hoped that by constructing and sharing models students would develop deeper understanding of concepts and the relationships between them.

In keeping with a strong focus currently in the ICTMA research community on the modelling competency construct, section three, *Recognising modelling competencies*, consists of nine chapters eight of which report research in secondary schooling or university contexts. Kaiser, for example, describes a university program for pre-service teachers at Hamburg University which links mathematicians, mathematics teacher educators and secondary schools. As part of the program upper secondary

students (aged 16–18 years) work in groups with their teachers and pre-service teachers (in class or after school) on one modelling example over an extended period (three and a half months). There is also the possibility of continuing into another semester and working on a second problem. The problems are usually proposed by applied mathematicians working in industry. Kaiser describes a group attempt to solve the problem of how a discount airline determines its fare prices. To monitor development of modelling competencies by the upper secondary school students over the duration of the program, three versions of multiple choice item tests (from the work of Haines, Crouch & Davis, 2001; Houston & McNeill, 2003; and Izard, Haines, Crouch, Houston & Neill, 2003) were used at the beginning of the program, after the first modelling task and after the second modelling task, respectively. These tests are said to measure cognitive but not metacognitive modelling sub-competencies. The results showed that sub-competencies can be developed using a program such as the one described; however, in some areas, students at first developed apparent expertise then regressed "indicating that long processes are necessary in order to provide a solid base for steady improvements" (p. 118). This finding was in keeping with Haines and Crouch (2003) who point out that with complex tasks students' apparent expertise often becomes worse before improving. The remaining chapter in the section is by Jiang, Xie and Ye who describe *the China undergraduate mathematical contest in modelling*. This has become a very popular competition in China and has had the flow-on effect that Chinese representation in USA modelling contests is very strong. The authors then describe an interesting problem from the 2004 contest where students had to plan the location and stocking of small and large size temporary mini supermarkets selling food, souvenirs and tourist commodities to spectators, tourists and workers at the Olympic Games venues.

Everyday aspects of modelling 'literacy' is the topic of the fourth section which consists of five chapters. Julie, for example, sees mathematical literacy as dealing "primarily with the insertion of a mathematical gaze on extra-mathematical issues and situations" (p. 195). He points out that student preferences for topics to investigate in such situations are an under-researched area despite the commonly espoused belief that motivating student interest in mathematics is a goal of the use of real-world contexts. Years 8, 9 and 10 students (aged 12–23 years but mainly in range 13–18) from low socio-economic status areas of South Africa were asked to indicate their preferences for particular topics and issues presented to them. The students' first preference was for issues dealing with health. This interest was attributed to their personal knowledge about health and consequences of ill-health heightened by media and school

programs focussing on these. On the other hand, agricultural matters which are often depicted in the media as involving hardship, discrimination, unsatisfactory living conditions and lack of opportunity were of least interest. Further examination of the data revealed "keen interest in the mathematics dealing with modern things which young people [whatever their socio-economic status] perceive as indispensable" (p. 199) such as mobile phones and security codes and pins. Financial planning for profit making was also of high interest again fuelled by media campaigns. Of least interest, after agricultural matters, were mathematics in elections, cultural artefacts such as house decorations, and in the lottery or gambling. Julie speculates that "learners' preferences were influenced by the bureaucratic visibility of the issues that comprised the survey instrument" (p. 201). He points out that learners' preferences are "transitive and time-dependent". However, as well as choosing topics that are "personally relevant" to learners in a mathematical literacy context, it is also important to foreground issues "which learners do not as yet perceive as interesting" (p. 201).

Cognitive perspectives on modelling is also a current research interest of many in the ICTMA community with this section of the book comprising nine chapters, although it must be said that some of the researchers in the previous sections also use (or have used) a cognitive lens during their analyses. Borromeo Ferri, however, sees "looking at modelling from a cognitive perspective" as largely "neglected in the current discussion regarding modelling" (p. 260). In her chapter she links mathematical thinking styles (identified as visual, analytical and intergrated) to modelling activity, namely the transfer processes students perform in order to translate from the real world model to the mathematical model. In the context of year 10 German classrooms with students aged 16 years old using more complex contextual tasks which expliciltly included modelling processes, it was possible to reconstruct teachers' mathematical thinking styles and to see that teachers' with different mathematical thinking styles focussed on different aspects of the modelling cycle when discussing solutions. For instance, a visual thinker interpreted and validated the modelling processes with students placing special emphasis on the real situation described in the task context. In contrast, a more analytical teacher focussed less on interpretation and validation and gave less emphasis to the real situation focussing more on formalisation of the task in the form of abstract equations. To show the non-cyclical nature of the modelling pathways of students, Borromeo Ferri used the Blum and Leiß (p. 260–231) form of the modelling cycle diagram to reconstruct these modelling pathways for students with different mathematical thinking styles. Borromeo Ferri asserts that "an individual's style influences the

way in which the modelling process is carried out" (p. 268). Analytical thinkers leave the real model quickly to work on the mathematical model and only return if the task context needs clarification. "They work mainly in a formalistic manner and are better at 'perceiving' the mathematical aspects of a given real situation. Visual thinkers, on the other hand, often imagine the situation in pictures and often use pictographic drawings. Switching between the mathematical and real model is frequent", as they attempt to get a better understandoing of the task context (p. 268).

The section, *The practice of modelling*, contains many modelling and application examples from practice including energy issues related to the use of fossil fuels and renewable alternatives such as wind turbines, ecological issues such as fishing quotas and how to model the mating strategies of lizards, leak detection in a pipeline, length of cable on a reel, billiards, fractal image compression, *the lottery of casanova*, *the catwalk problem*, high speed optical food sorting machines, heat flow in work rolls used for hot rolling of steel strips in a continuous mill, modelling of multi-strand, multi-segment power cables and multi-layer printed circuit boards. Examples in this section would be of use in secondary school and tertiary teaching in areas such as engineering but also pre-service and in-service secondary mathematics teacher education. Our focus will be the catwalk problem. In their chapter, Lingfjärd and Holmquist examine whether using real world phenomena makes a difference to how pre-service teachers approach a problem. In the catwalk problem students need to build connections between local rates of change and total changes based on real-world data. A series of photographs shows a cat changing from a walking gait to a gallop. Students were asked to make one or two models describing how the cat moved over the time period of the photographic sequence. The authors discuss the students' approaches and the role of writing in the investigative process used in the modelling task which was part of the students' assessment.

The chapters in the final section, *Behaviours in engineering and applications*, mainly overview and evaluate several courses in architecture, engineering, calculus, physics, modelling in pre-service middle school teaching, introductory and advanced level mathematical modelling (through a national Virtual University in Finland), modelling and computing, and modelling and software design. Franchi observes that "Computing has brought new possibilities for modelling. Many of the difficulties of the modelling process were overcome by the facility of data collection and treatment and by the ease of representations possible through particular software. The model can be constructed with more freedom without being concerned about complex mathematics, or that that mathematics might be difficult for certain school levels" (p. 475). Franchi's

"characterization of learning environments through mathematical modelling and computing" leads to two cases: (1) "study of a real situation, by means of mathematics, using computing to organize and to represent collected data and to solve equations" and (2) "study of a mathematical subject that can characterise a phenomenon of the reality, using software to work with characteristics and relevant content properties" (p. 475). An example is given using the theme of controlling populations of the mosquito that causes Dengue fever in tropical areas such as North Queensland and Brazil.

Books of this nature are a challenge for their editors to assemble very different individual contributions into some united whole. What unites the writers in this volume is that in some way they are concerned with the researching, teaching, and/or practice of mathematical modelling and/or applications. As such, the volume makes a valued contribution to the published knowledge in this field.

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