

Preface

This book is a description of research and data analysis carried out by the authors with substantial funding from the National Center for Education Statistics (NCES) and the Institute of Education Sciences (IES), divisions of the U.S. Department of Education, in partnership with the American Institutes for Research (AIR). The purpose of this work was to evaluate a new approach to the analysis and reporting of the large-scale surveys for the National Assessment of Educational Progress (NAEP) carried out for the NCES.

The new approach was based on a full statistical and psychometric model for students' responses to the test items, taking into account the design of the survey, the backgrounds of the students, and the classes, schools and communities in which the students were located.

The need for a new approach was driven by two unrelated issues: the demands for *secondary analysis* of the survey data by educational and other researchers who needed analyses more detailed than those published by NCES, and the need to accelerate the processing and publication of results from the surveys.

The modeling approach is complex and computationally intensive, but less so than the existing methods used for these surveys, and it has the twin advantages of *efficiency* in the statistical sense – making full use of the information in the data – and *optimality*: given the validity of the statistical model, this form of analysis is superior to any other non-Bayesian analysis in terms of precision of the estimates of group differences and regression coefficients of important variables.

The use of a full statistical model avoids the ad hoc methods that are otherwise necessary for the analysis of the data. It is dependent, for successful adoption, on efficient computational implementations in generally available software. Developments in this area have been rapid in the last ten years: we began our analyses in 2003 using Gllamm in Stata (Rabe-Hesketh and Skrondal 2005); see the Website.

<http://www.gllamm.org>

By 2008 we were able to use the very fast Latent Gold program which makes large-scale model fitting straightforward for NAEP data sets; see the Website.

http://www.statisticalinnovations.com/products/latentgold_v4.html

The following chapters, apart from the first, are set out in a sequence representing the main aspects of the NAEP surveys and the development of methods for fitting the increasingly complex models resulting from the incorporation of these aspects. The content of the book is drawn mostly from our NCES research reports, which are described briefly in Chapter 4. We generally do not give references to specific reports in the text, as the chapters draw from many of the reports. The full reports themselves are available on our Website, as described in Chapter 4.

The models and analysis approach are illustrated with detailed results from two NAEP surveys. The first is from the 1986 national NAEP mathematics test and includes results on the set of 30 items from the Numbers and Operations: Knowledge and Skills subscale, for age 9/grade 3 children. The “explanatory” regression model fitted is quite small and was chosen to nearly replicate the tables of “reporting group” variables published by NCES for this survey. We extended this analysis to all 79 test items on three scales.

The second survey is from the 2005 national NAEP mathematics test and includes results on the set of 70 items from the Numbers and Operations scale for age 10/grade 4 children. We fitted a much larger regression model with variables from the student, teacher and school questionnaires. We analysed the California and Texas state subsamples with more complex item response models.

Chapter 1 is an introduction to the current theories of data analysis used for large-scale surveys. It may surprise non-statistician readers to find that there are major disputes within the statistics profession about the role of statistical models in official (national government) survey analysis. We describe the critical theoretical issues that divide the several theories, and give an indication of the extent to which each theory is used in current official practice.

Chapter 2 describes the current method of analysis of NAEP surveys. This has changed several times; we give the analysis that was used for the 1986 survey, which we use as an illustration in later chapters, and note the changes that have occurred since then. The design and analysis of the 1986 survey were very complicated, and we have omitted aspects of the design that are not critical to the analysis. Some complex sections (for example, jackknifing) have been described at length because these are critical for the comparison with our approach.

Chapter 3 sets out the psychometric models used in the NAEP analysis, gives some extensions of them using mixture distributions for student ability, discusses the survey designs used in the surveys, and gives the multilevel model representation of the designs.

Chapter 4 summarises the main conclusions from our extensive simulation studies, which showed the improvement in precision and the reduction in bias resulting from the fully model-based analysis of small-scale models compared with the current approach. References to the full reports on this work are given there.

Chapter 5 sets out the series of analyses we used with the range of models from Chapter 3 for the 30-item scale from the 1986 math test for age 9/grade 3 children. Chapter 6 extends these analyses to the full set of 79 items on the test. Chapter 7

applies more complex analyses to the 2005 national NAEP subsample for Texas for age 10/grade 4 children. Chapter 8 applies the same analyses to the 2005 subsample for California for age 10/grade 4 children.

Chapter 9 discusses the results of the analyses and draws conclusions about the benefits and limitations of fully model-based large-scale survey analysis.

Acknowledgements

Murray's interest in psychometric modeling began with his post-doctoral position with Lyle Jones at the Psychometric Laboratory, University of North Carolina at Chapel Hill in 1966–67, and developed substantially from his visiting year as a Fulbright Senior Fellow in Frederic Lord's psychometric research group at the Educational Testing Service (ETS), Princeton in 1971–72.

In his large-scale research programme on EM algorithm applications to incomplete data problems at the University of Lancaster 1979–85, Murray developed with Darrell Bock (Bock and Aitkin 1981) an EM algorithm for the 2PP model. This algorithm has been very widely extended to other psychometric models.

Murray returned to ETS as a Visiting Scholar in 1987–88. Here he reviewed (Aitkin 1988) the extent to which hierarchical variance component modeling, incorporating the survey design in additional levels of the model, could be used for the analysis of NAEP data, and the possible information that it could provide. He noted that fitting the 3PL model in a full hierarchical model was beyond the capabilities of available programs, and suggested variations to the E step of the EM algorithm that could give an approximate analysis.

Our joint interest in NAEP developed with Murray's appointment as Chief Statistician at the Education Statistics Services Institute (ESSI), American Institutes for Research, in Washington, D.C. in 2000–2002, as a senior consultant to NCES. It continued through a series of research contracts with NCES through AIR in subsequent years.

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