
Digital Module 13: Monte Carlo Simulation Studies in IRT

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Available in the ITEMS Portal at <https://ncme.elevate.commpartners.com>

Module Overview

In this digital ITEMS module, Dr. Brian Leventhal and Dr. Allison Ames provide an overview of *Monte Carlo simulation studies* (MCSS) in *item response theory* (IRT). MCSS are utilized for a variety of reasons, one of the most compelling being that they can be used when analytic solutions are impractical or nonexistent because they allow researchers to specify and manipulate an array of parameter values and experimental conditions (e.g., sample size, test length, and test characteristics). Dr. Leventhal and Dr. Ames review the conceptual foundation of MCSS in IRT and walk through the processes of simulating total scores as well as item responses using the two-parameter logistic, graded response, and bi-factor models. They provide guidance for how to implement MCSS using other item response models and best practices for efficient syntax and executing an MCSS. The digital module contains sample SAS code, diagnostic quiz questions, activities, curated resources, and a glossary.

Key words: bias, bi-factor model, estimation, graded response model, item response theory, mean squared error, Monte Carlo, simulation, standard error, two-parameter logistic model

Prerequisite Knowledge

This ITEMS module assumes no prior knowledge of Monte Carlo simulation methods. However, to get the most out of this module, it might be beneficial to have a basic understanding of:

- Unidimensional IRT models such as the 1-, 2-, or 3-parameter logistic models and the graded response model
- Two-dimensional IRT models such as a multidimensional IRT model or a bifactor model
- Basic programming experience and procedures in a common language, ideally SAS

Reading the following NCME ITEMS modules may serve as a useful introduction to the prerequisite knowledge:

- Module 7: Dichotomous IRT Models I: A comparison (Harris, 1989)
- Module 35: Polytomous IRT Models I: Overview of Models (Penfield, 2014)
- Module 42: Assessment Procedures VII: Simulation Studies (Feinberg & Rubright, 2016)

These modules and others are available for free in the ITEMS portal.

Learning Objectives

Upon completion of this ITEMS module, learners should be able to:

- Articulate the major considerations of a Monte Carlo simulation study,
- Identify important SAS procedures and techniques for data simulation,
- Adapt basic simulation techniques to IRT-specific examples, and
- Extend examples to more complex models and scenarios.

Module Structure

The digital module is divided into the following sections, which can be reviewed sequentially or independently [*approximate completion times in parentheses*].

- Module Introduction [*5 Minutes*]
- Section 1: Conceptual Foundations [*30 Minutes*]
- Section 2: Total Score Simulation [*10 Minutes*]
- Section 3: 2PL Model [*30 Minutes*]
- Section 4: Graded Response Model [*20 Minutes*]
- Section 5: Bifactor Model [*15 Minutes*]
- Section 6: Simulation Activity [*30 Minutes*]
- Section 7: Quizzes [*20 Minutes*]

In the portal site, you can also find a video version of the core content as well as a handout with all core slides along with other materials.

Module Components

This ITEMS module includes the following components, which are delivered within a web-delivered unified design shell that is compatible across platforms (i.e., laptops, desktops, tablets, cell phones) and was created with modern course development software (*Articulate 360*):

- integrated content slides that provide a structured walk-through of the content with suitable voice-over
- embedded didactic videos to demonstrate software implementations
- interactive quiz questions
- data activity sample SAS code and annotated solutions
- glossary of key terms
- supplementary digital resources

Additional materials may be added over time so check back periodically!

Content Developers

Brian C. Leventhal, *Assistant professor at James Madison University*



Brian is an assistant professor in the Assessment and Measurement PhD program in the Department of Graduate Psychology at James Madison University as well as an assistant assessment specialist in the Center for Assessment and Research Studies at James Madison University. There, he teaches courses in quantitative methods, including a course on Simulation Studies in Psychometrics. Brian received his Ph.D. from the University of Pittsburgh. His research interests include multidimensional item response models that account for response styles, response process models, and classification errors in testing. Brian is passionate about teaching and providing professional development for graduate students and early-career practitioners. He has thoroughly enjoyed collaborating with Allison Ames and the Instructional Design Team to develop this module.

Allison J. Ames, *Assistant professor at the University of Arkansas*



Allison is an assistant professor in the Educational Statistics and Research Methods program in the Department of Rehabilitation, Human Resources and Communication Disorders, Research Methodology, and Counseling at the University of Arkansas. There, she teaches courses in educational statistics, estimation methods, and other topics. Allison received her Ph.D. from the University of North Carolina at Greensboro. Her research interests include Bayesian item response theory, with an emphasis on prior specification; model-data fit; and models for response processes. Her research has been published in prominent peer-reviewed journals. She enjoyed collaborating on this project with the Instructional Design Team and her colleague, Dr. Leventhal.

Instructional Design Team

Jonathan Lehrfeld, *Psychometrician at Educational Testing Service (ETS)*



Jon graduated from Fordham University in 2016 with a Ph.D. in psychometrics and quantitative psychology, where his dissertation focused on integrating propensity score methods with structural equation modeling. After graduating, he worked at the Council for Aid to Education (CAE) for three years, serving as their psychometrician and Associate Director of Measurement Science. While at CAE, his operational and research work focused on practical problems in low-stakes testing. He most recently joined ETS where he currently works as a psychometrician on a large-scale state assessment team.

André A. Rupp, Independent Consultant



André is the co-author and co-editor of two award-winning interdisciplinary books entitled *Diagnostic Measurement: Theory, Methods, and Applications* (2010) and *The Handbook of Cognition and Assessment: Frameworks, Methodologies, and Applications* (2016) and has just published the *Handbook of Automated Scoring: Theory into Practice* (2020). His research synthesis- and framework-oriented work has appeared in a wide variety of prestigious peer-reviewed journals. Among other things, he is passionate about improving processes for interdisciplinary collaborations during the development and implementation of scoring solutions for digitally-delivered assessments. Consequently, he is very excited to serve as the associate editor / lead instructional designer of the ITEMS portal for NCME whose mission is to provide free digital resources to support self-directed learning and professional development.

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