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## Digital Module 11: Bayesian Psychometric Modeling

Roy Levy, Arizona State University

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### Module Overview

In this digital ITEMS module, Dr. Roy Levy describes Bayesian approaches to psychometric modeling. He discusses how Bayesian inference is a mechanism for reasoning in probability-modeling framework and is well-suited to core problems in educational measurement: reasoning from student performances on an assessment to make inferences about their capabilities more broadly conceived as well as fitting models to characterize the psychometric properties of tasks. The approach is first developed in the general context of estimating a mean and variance of a normal distribution before turning to the context of unidimensional item response theory (IRT) models for dichotomously scored data. Dr. Levy illustrates the process of fitting Bayesian models using the JAGS software facilitated through the R statistical environment. The module is designed to be relevant for students, researchers, and data scientists in various disciplines such as education, psychology, sociology, political science, business, health and other social sciences. It contains audio-narrated slides, diagnostic quiz questions, and data-based activities with video solutions as well as curated resources and a glossary.

*Keywords:* Bayesian psychometrics, Bayes theorem, dichotomous data, item response theory (IRT), JAGS, Markov-chain Monte Carlo (MCMC) estimation, normal distribution, R, unidimensional models

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### Prerequisite and Related Knowledge

This ITEMS module assumes no prior knowledge of Bayesian statistics. However, it is probably helpful to have a working knowledge of foundational assessment and statistical concepts such as:

- Basic descriptive statistics (e.g., mean, standard deviation)
- Normal distributions and their features (e.g., mean, variance)
- Goals of statistical analyses in assessment (e.g., estimating proficiency variables for examinees, estimating parameters for tasks)
- Unidimensional item response theory models for dichotomous data
- Statistical expressions of probability and conditional probability

The following NCME ITEMS modules may serve as a useful introduction to relevant prerequisite knowledge:

- Digital Module 6: Posterior Predictive Model Checking
- Module 27: Markov Chain Monte Carlo Methods for Item Response Theory Models
- Module 16: Comparison of Classical Test Theory and Item Response Theory
- Module 7: Comparison of 1-, 2-, and 3-Parameter IRT Models

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

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## Learning Objectives

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

- Identify the key components (distributions) in Bayes' theorem
  - Explain the conceptual foundations of the Bayesian approach to measurement
  - Articulate advantages of Bayesian statistical inference
  - Set up and execute a Bayesian analysis for normal distributions and unidimensional IRT models
  - Interpret the results of a Bayesian analysis in terms of person and task parameters
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## Module Structure

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

- Module Overview [*5 Minutes*]
- Section 1: Bayesian Inference [*15 Minutes*]
- Section 2: Normal Distributions [*30 Minutes*]
- Section 3: Item Response Theory [*35 Minutes*]
- Section 4: Data Activities [*60 Minutes*]
- Section 5: Quizzes [*10 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.

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## 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
- embedded didactic videos to demonstrate software implementations
- interactive quiz questions with diagnostic feedback
- sample data and syntax files for all examples and activities
- data-based activities with video solutions
- glossary of key terms
- supplementary digital resources

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

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## Instructor

**Roy Levy**, *Professor at Arizona State University*



Roy is a professor in the T. Denny Sanford School of Social & Family Dynamics at Arizona State University, specializing in Measurement and Statistical Analysis. He received his Ph.D. in Measurement, Statistics & Evaluation from the University of Maryland. His research and teaching interests include methodological investigations and applications in psychometrics and statistical modeling, focusing on item response theory, structural equation modeling, Bayesian networks, and Bayesian approaches to inference and modeling, as well as evidentiary principles and applications in complex assessments. He is the co-author of the book *Bayesian Psychometric Modeling*, and has published his work in a variety of leading methodological journals. For his work, he has received awards from the National Council on Measurement in Education, the American Educational Research Association, and the President of the United States. He currently serves on the editorial boards for *Structural Equation Modeling: A Multidisciplinary Journal*, *Educational Measurement: Issues and Practice*, *Measurement: Interdisciplinary Research and Perspectives*, and *Educational Assessment*.

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## Instructional Designer

**André A. Rupp**, *Research Director at Educational Testing Service (ETS)*



André is a research director in the psychometrics, statistics, and data sciences area at ETS. He 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); he is currently working on the *Handbook of Automated Scoring: Theory into Practice*. His synthesis- and framework-oriented research 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 developer of the ITEMS portal for NCME whose mission is to provide free digital resources in educational measurement to support self-directed learning and professional development.

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***This is the pre-peer reviewed version of the following article: Levy, R. (2020). Bayesian psychometric modeling (ITEMS Digital Module 11). Educational Measurement: Issues and Practice, 39(1). It has been published in final form at <https://onlinelibrary.wiley.com/journal/17453992>. This article may be used for non-commercial purposes in accordance with Wiley Terms and Conditions for Use of Self-Archived Versions.***

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