Understanding the Quantitative and Computational Skills of Incoming Biology Students (BioSQuaRE)

***Bio**logy **S**cience*
***Qua**ntitative*
***R**easoning **E**xam*

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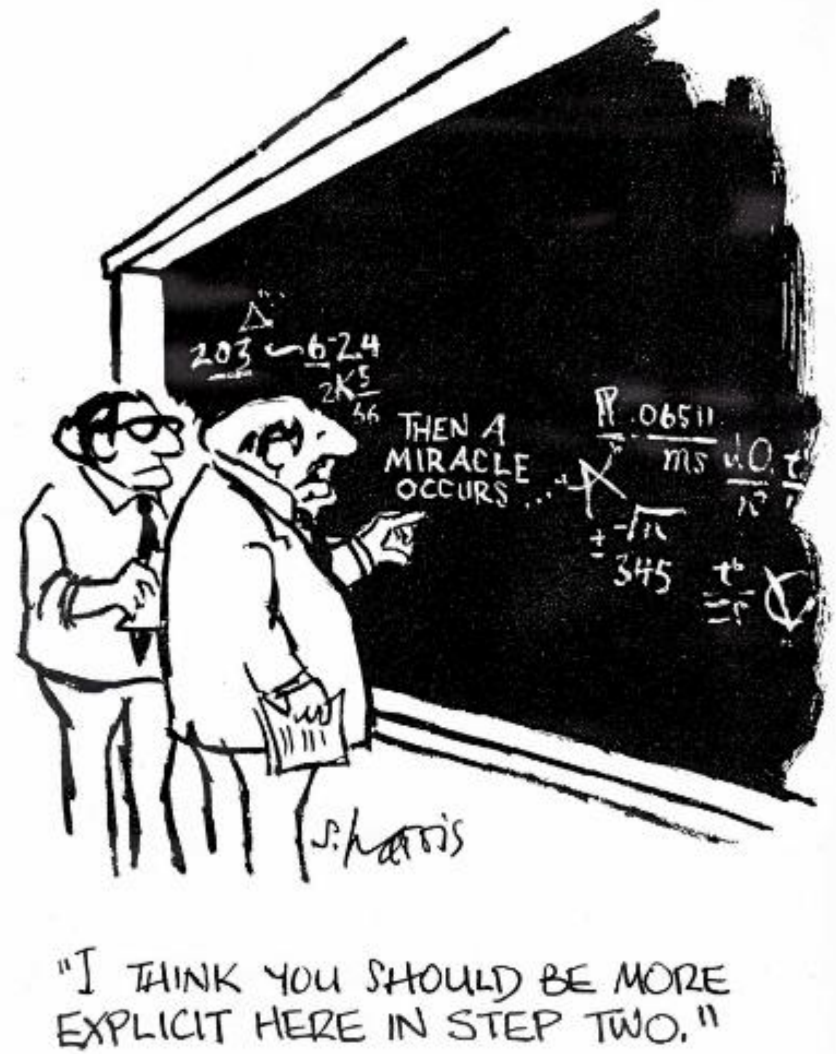
Normal, IL

hhmi Howard Hughes Medical Institute



BioSQuaRE Team

Biology

Paul Overvoorde (Macalester)
Peter Brodfuehrer, Greg Davis (Bryn Mawr)
Marion Preest (Keck Science Center, Claremont Colleges)
Steve Adolph, Cathy McFadden (Harvey Mudd)

Educational Psychology/Statistics

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Laura Ziegler (Iowa State)

Other

Liz Stanhope (Lewis and Clark) – Math
Jason Belitsky (Oberlin) – Chemistry
Marcelo Vinces (Oberlin) – Quantitative Skills Center
Tabassum Haque (Oberlin) – Institutional Research

Motivation

Molecular Biology of the Cell Perspective November 2014

Teaching quantitative biology: goals, assessments, and resources

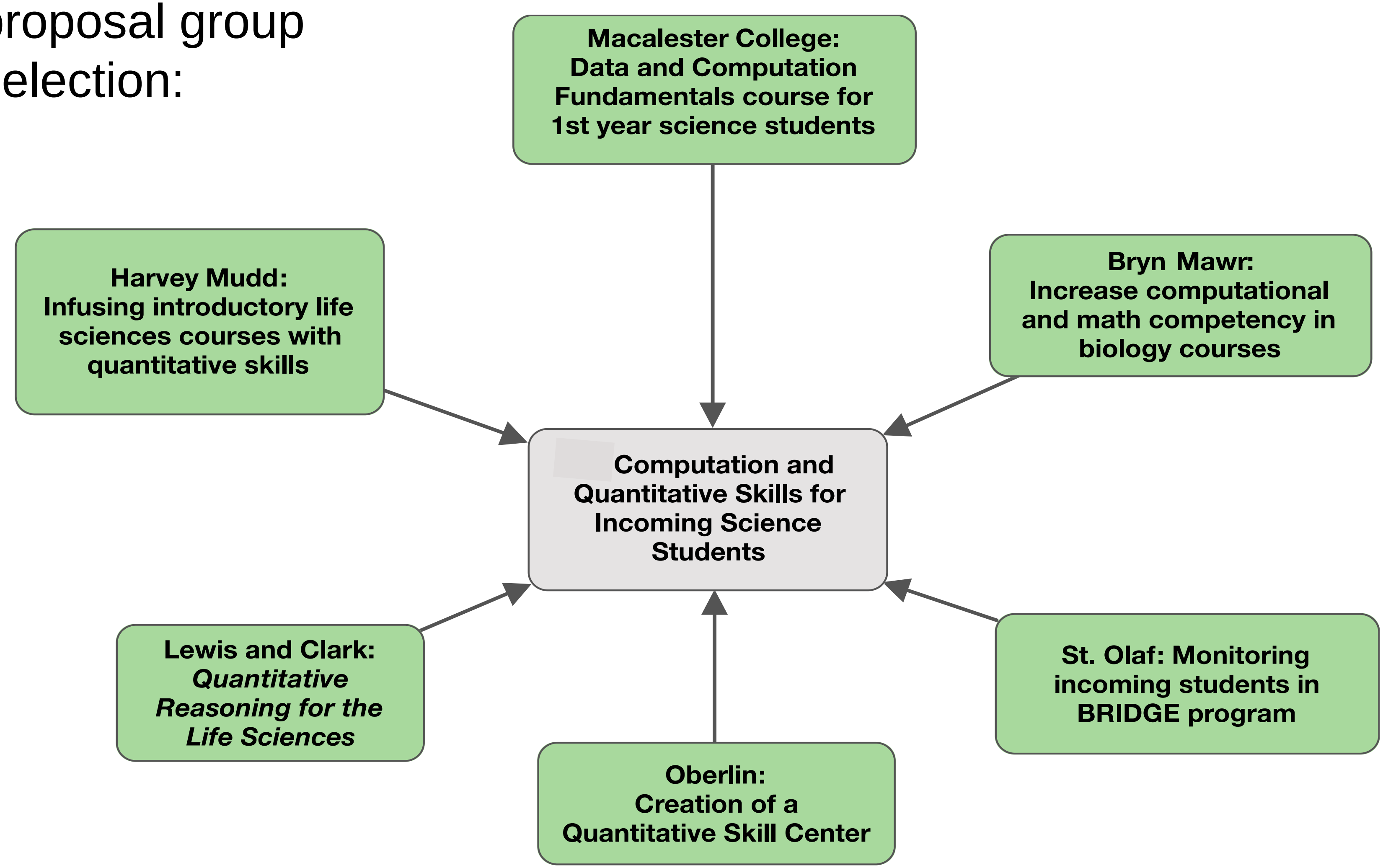
Melissa L. Aikens and Erin L. Dolan
Texas Institute for Discovery Education in Science, College of Natural Sciences, University of Texas, Austin, TX 7

ABSTRACT More than a decade has passed since the publication of *BIO2010*, calling for an increased emphasis on quantitative skills in the undergraduate biology curriculum. In that time, relatively few papers have been published that describe educational innovations in quantitative biology or provide evidence of their effects on students. Using a "backward design" framework, we lay out quantitative skill and attitude goals, assessment strategies, and teaching resources to help biologists teach more quantitatively. Collaborations between quantitative biologists and education researchers are necessary to develop a broader and more appropriate suite of assessment tools, and to provide much-needed evidence on how particular teaching strategies affect biology students' quantitative skill development and attitudes toward quantitative work.

Mol. Biol. Cell **2014**, *25*, 3478-3481

Actual Motivation

October 2012 – HHMI Program Director’s Meeting, collaborative proposal group selection:



Graphic – Paul Overvoorde (Macalester)

BioSQuaRE

Target Populations:

(1) Students entering or prior to biology intro sequence (**"pre"**)
(2) Biology majors beyond intro sequence (**"post"**)

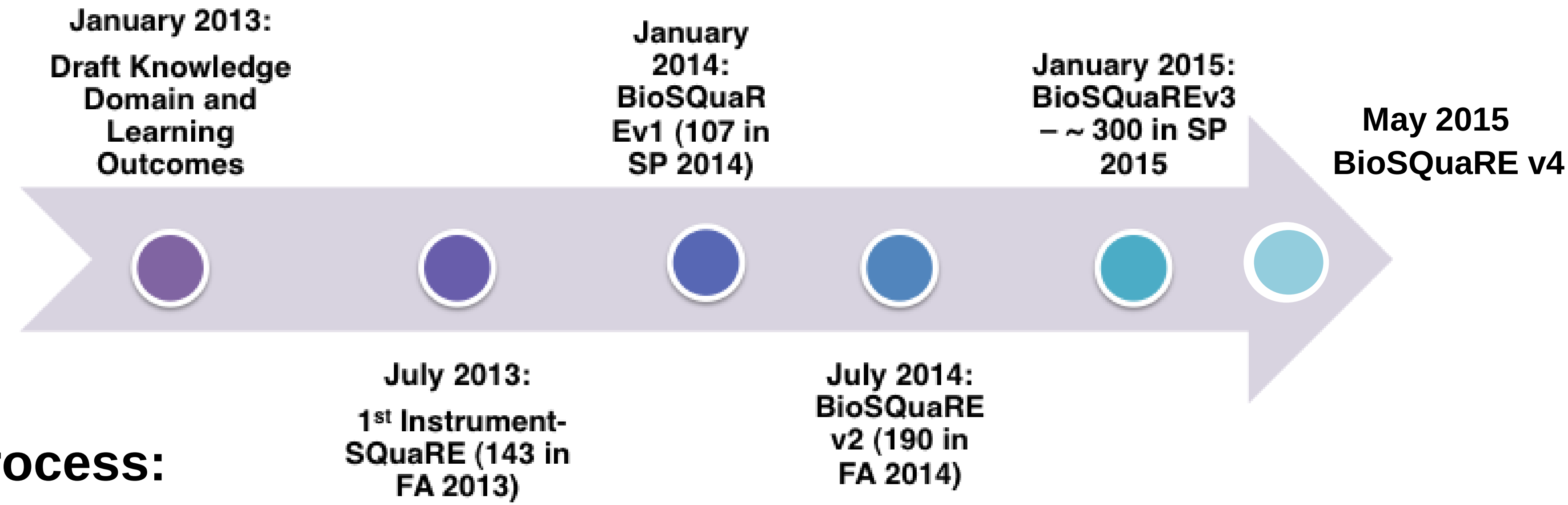
Focus Areas:

Algebra, Probability, Statistics, Modeling, Visualization **

Utility:

- **Individual Student**
- **Individual Faculty Member**
- **Department/Institution**

BioSQuaRE Development



Process:

SQuaRE – mix of multiple choice and open-ended questions to generate distracters.

BioSQuaRE v1 – mostly multiple choice

BioSQuaRE v2 – almost all multiple choice

BioSQuaRE v3 – all multiple choice

BioSQuaRE v4 – elimination/modification of redundant/problematic questions, ready for general use.

Increasing **Biological Context** and Percent of **Visualization** Questions

BioSQuaRE v3

Topic	Learning Outcome	BioSQuaRE question number
Visualization	Be able to choose the appropriate type of graph.	2
	Be able to interpret a graph (e.g., functional relationships, logarithmic relationships).	10, 15, 16, 17, 18, 19, 20, 24, 25, 26, 27, 28
	Examples: heat map, clustering, time as independent variable, saturation curve, multidimensional representations	
	Be able to use a table to perform computations.	7, 8, 14
Statistics	Understand what summary statistics represent.	10, 21, 22, 23
	Examples: mean, median, standard deviadtion, standard error, proportions	
	Be able to recognize types of error.	7, 9, 14
	Examples: systmatic vs. noise; precision vs. accuracy	
	Be able to recognize that biological systems are inherently variable (e.g., stochastic vs. deterministic)	7
	Be able to formulate hypothesis statements.	11
	Be able to make an evidence-based decision.	12, 20
	Example: p-value interpretation	
	Understand when causal claims can be made (e.g., correlation vs. causation).	13
	Understand when generalizations can be made.	
Modeling	Be able to fit a model such as population growth.	
	Use a representation or a model to make predictions.	3, 14, 16
	Example: decision tree, graph to forumla	
Algebra	Be able to carry out basic mathematical computations. (e.g. ratio/proportional reasoning, unit conversion, center and variation, calculate return on investment)	1, 3, 14, 21, 22, 23
Probability	Be able to calculate the likelihood of an event happening.	14
	Example: mutation rate	
	Understand logarithmic/exponential relationships.	8, 21, 22, 23

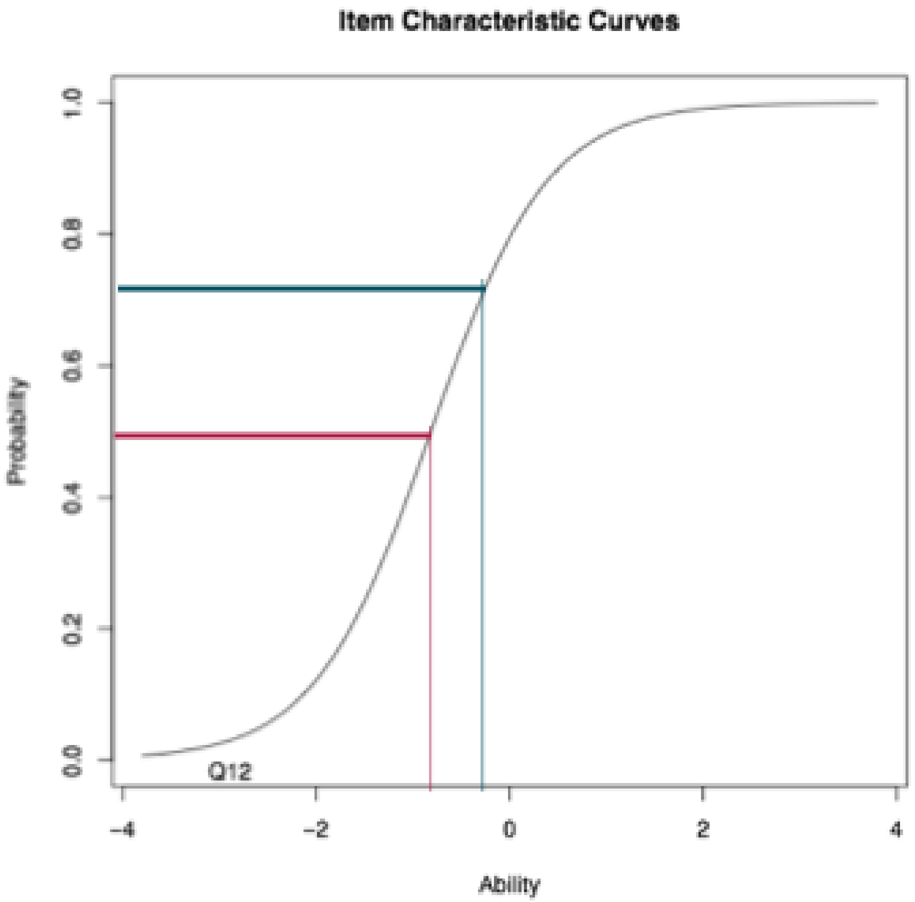
Topic	Learning Outcome	QLRA	TOSLS
Visualization	Choose the appropriate type of graph.		
	Interpret a graph (e.g., functional relationships, logarithmic relationships).		
	Be able to use a table.		
	Spatial reasoning and interpret multidimensional numerical and visual data (geographic information).		
Statistics	*Understand what summary statistics represent.*		
	Recognize types of error.		
	Recognize that biological systems are inherently variable (e.g., stochastic vs. deterministic).		
	Formulate hypothesis statements.		
	Understand what a p-value is.		
	Understand when causal claims can be made (e.g., correlation vs. causation).		
Modeling	Fit a model such as population growth.		
	Use a representation or a model to make predictions.		
	Describe/infer relationships between variables (scatterplots, regression, network diagrams, maps)		
	Perform logical/algorithmic reasoning		
Algebra and Functions	*Carry out basic mathematical computations. (e.g. ratio/proportional reasoning, unit conversion, center and variation, calculate return on investment)*		
	Understand logarithmic/exponential relationships.		
Probability	*Calculate or use the concept of the likelihood of an event.*		
	Understand conditional probability		

Examples of Test Items Removed

Please Contact Paul Overvoorde if you would need to see examples.

Item Response Theory

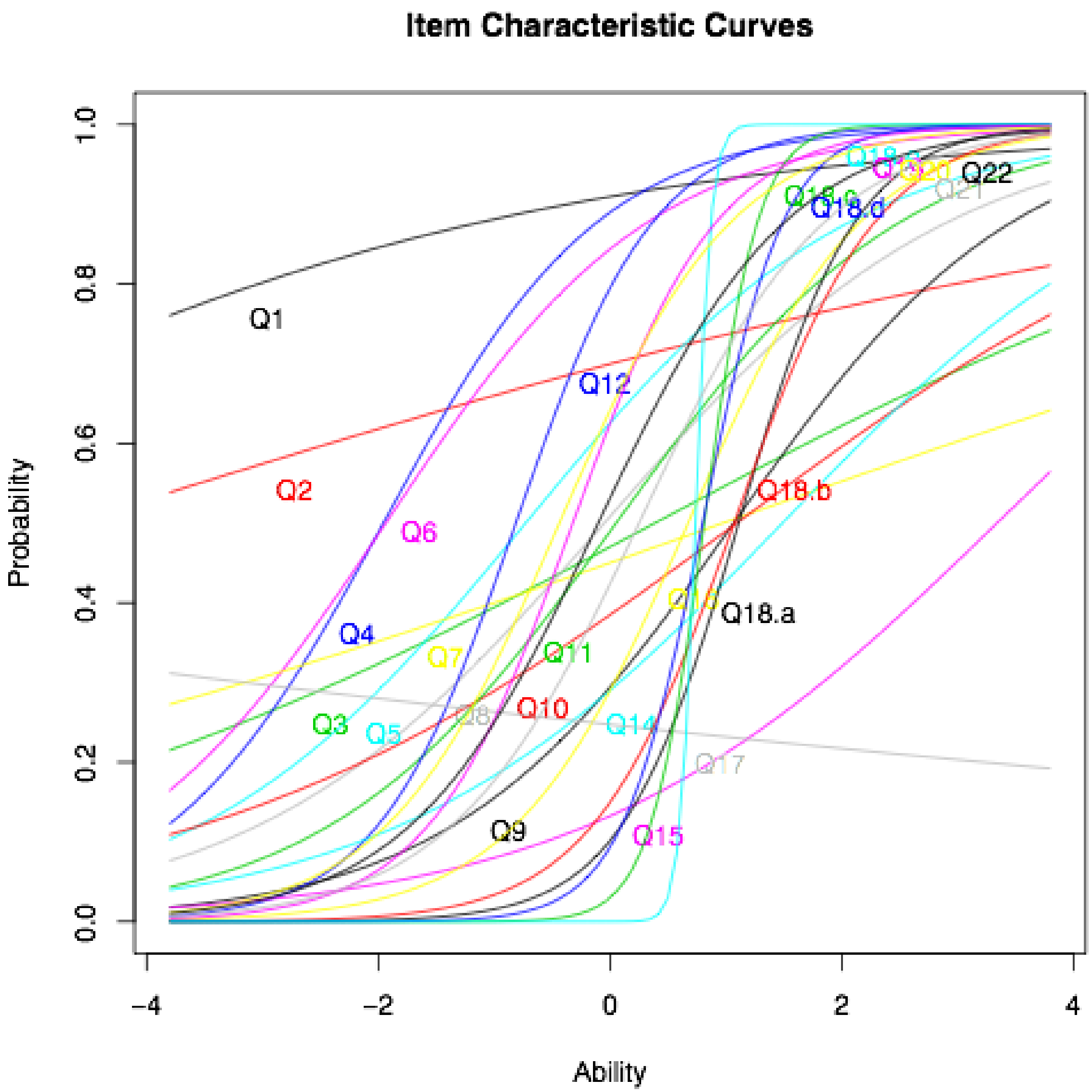
The probability of a correct response for a particular item can be depicted in the item characteristic curve (ICC).



<u>Item Discrimination</u>

Item discrimination is a measure of how well the item differentiates between lower and higher ability students. This can be seen in the "steepness" of the curve.

BioSQuaRE v2

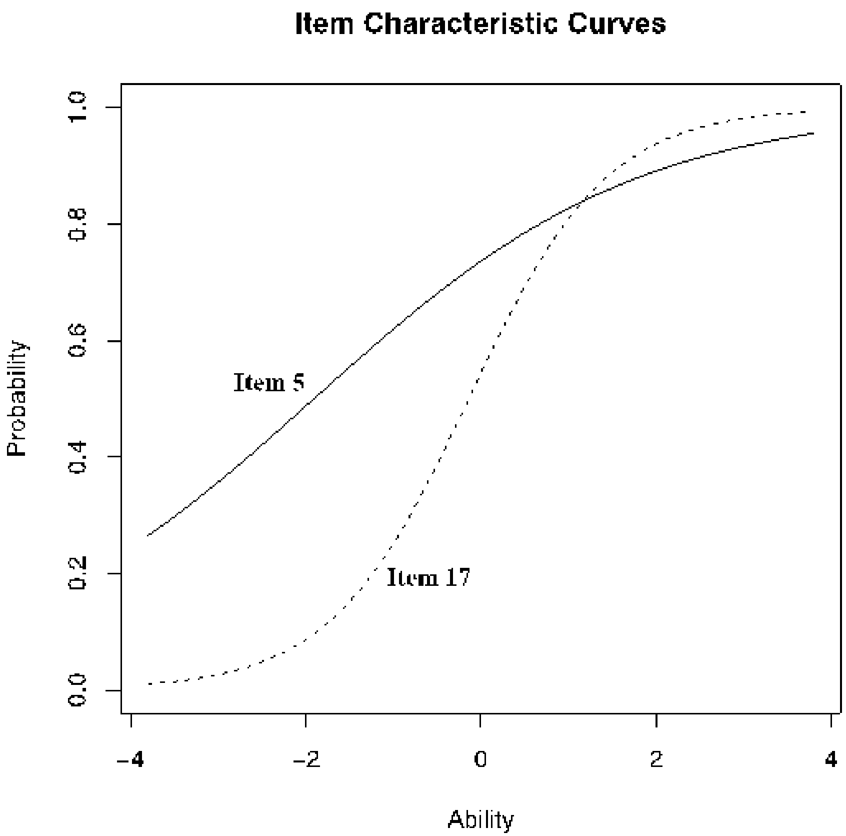


Here are the ICCs for all of the items on BIOSQUARE v2.

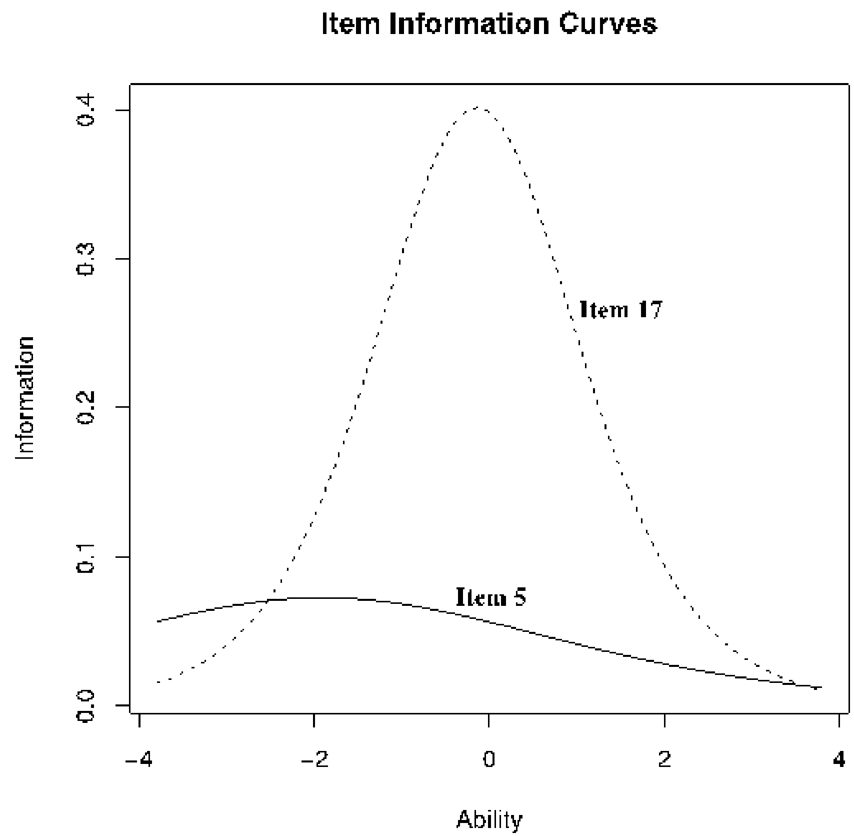
The items show a good range of difficulty.

Most items have reasonable discrimination.

Q17 is an example of a problematic item.

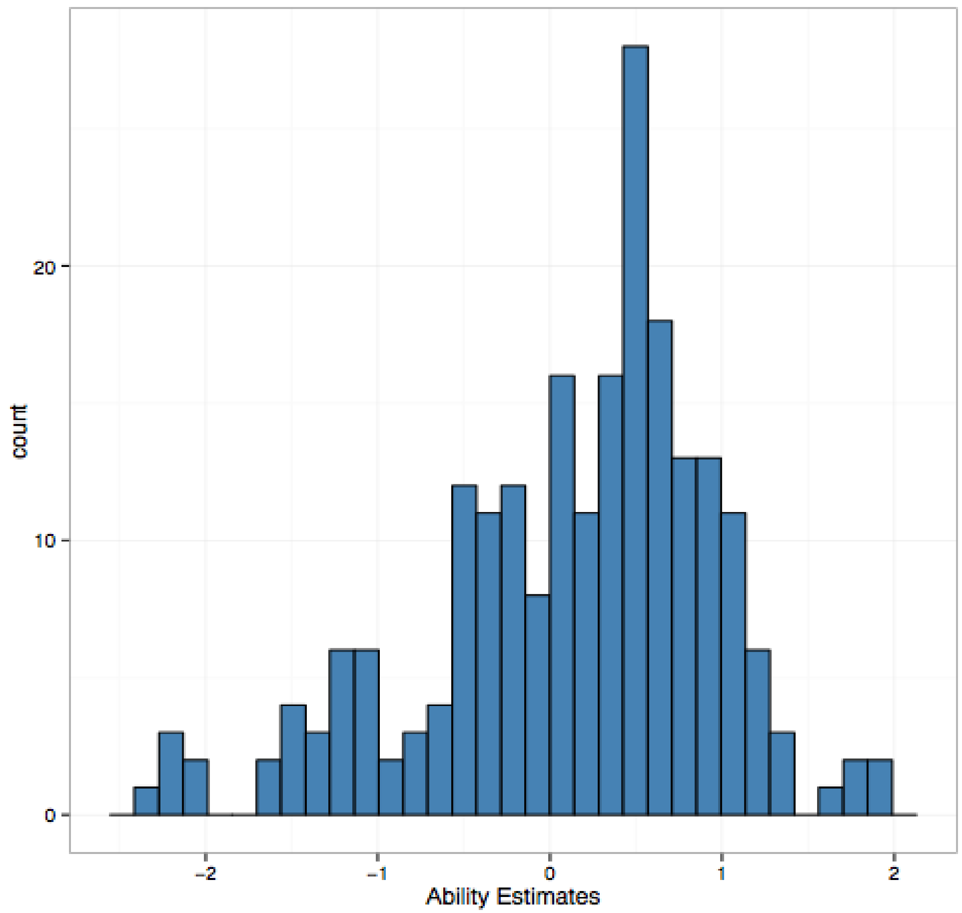


Item Characteristic Curves
Probability
1.0
0.8
0.6
0.4
0.2
0.0
Item 5
Item 17
-4
-2
0
2
4
Ability



Item Information Curves
Information
0.4
0.3
0.2
0.1
0.0
Item 17
Item 5
-4
-2
0
2
4
Ability

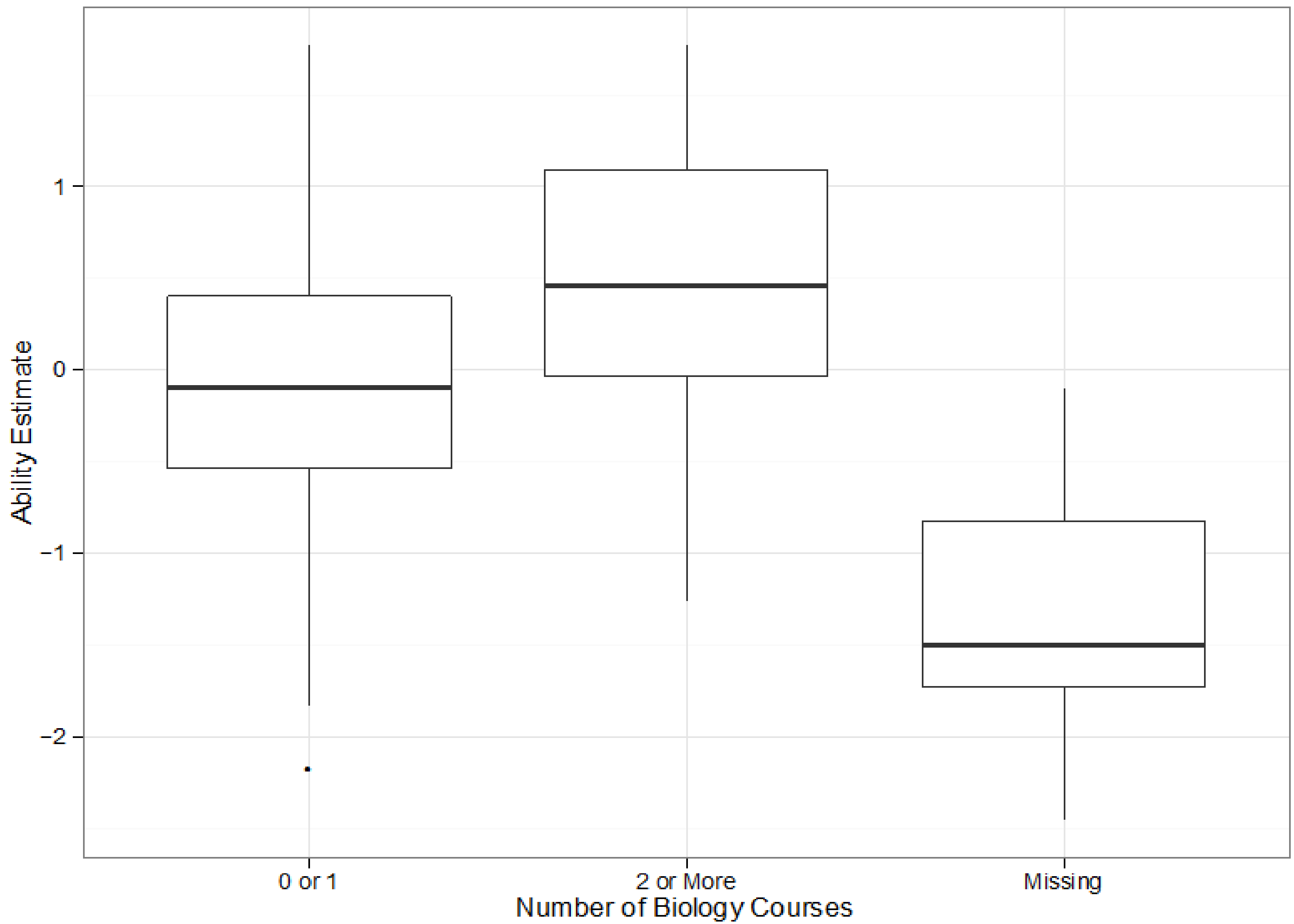
BioSQuaRE v2



Person Estimates

Once we know the item characteristics, we can use students' response patterns to estimate their ability level.

This suggests our sample included students with a wide range of ability levels.


Ability Estimate
1
0
−1
−2
0 or 1
2 or More
Missing
Number of Biology Courses

In Progress and Next Steps

-We have a link that allows instructors across the country to have their students take BioSQuaRE v4 (online, via Qualtrics) and a web site is coming soon.

https://umn.qualtrics.com/SE/?SID=SV_40dNrA9pn6WKvlj

(look forward to seeing how the test performs with a large range of institutions (beyond liberal arts) and types of students)

-We are working on a manuscript about the initial development of the instrument (in revision).

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