Table A1. Q-matrix for the TIMSS 4th grade mathematics

| Item | Number | | | Geometric Shapes and Measures | | | Data Display | Number of times specified |
	1. Whole Numbers	2. Fractions and Decimals	3. Number Sentences, Patterns, & Relationships	4. Lines and Angles	5. Two- and Three- Dimensional Shapes	6. Location and Movement	7. Reading, Interpreting, Organizing, & Representing	
1	1	0	0	0	0	0	0	1
2	0	1	0	0	0	0	0	1
3	1	1	0	0	0	0	0	2
4	1	1	0	0	0	0	0	2
5	1	0	1	0	0	0	0	2
6	0	0	0	0	1	1	0	2
7	0	0	0	1	1	1	0	3
8	1	0	0	0	1	0	0	2
9	0	0	0	0	1	0	0	1
10	0	0	0	1	1	0	0	2
11	1	0	0	1	0	0	0	2
12	1	0	0	0	0	0	1	2
13	1	0	0	0	0	0	1	2
14	1	1	0	0	0	0	1	3
15	1	0	0	0	0	0	0	1
16	1	0	0	0	0	0	0	1
17	1	0	1	0	0	0	0	2
18	1	0	1	0	0	0	0	2
19	1	0	0	0	0	0	1	2
20	1	0	1	0	0	0	1	3
21	1	0	1	0	0	0	0	2
22	0	0	0	0	1	1	0	2
23	1	0	0	0	0	0	0	1
24	0	0	0	0	1	0	0	1
25	1	0	0	0	0	0	1	2
Total	18	4	5	3	7	3	6	46

Note: Q-matrix based on Lee et al. (2011). Columns represent topic areas by content domain; attributes collapsed by topic areas.
Simulation studies using five attributes were based on collapsing attributes 2 and 3 and attributes 4 and 5.

Table A2. Item parameters: Covariate (science score)

Item	Domain	Item Parameter (l_j)		p-value
1	Number	0.15	(0.02)	< 0.001
2	Number	0.19	(0.02)	< 0.001
3	Number	0.12	(0.02)	< 0.001
4	Number	0.13	(0.02)	< 0.001
5	Number	0.23	(0.02)	< 0.001
6	Geometric Shapes and Measures	0.26	(0.05)	< 0.001
7	Geometric Shapes and Measures	0.15	(0.02)	< 0.001
8	Geometric Shapes and Measures	0.14	(0.02)	< 0.001
9	Geometric Shapes and Measures	0.18	(0.03)	< 0.001
10	Geometric Shapes and Measures	0.10	(0.02)	< 0.001
11	Geometric Shapes and Measures	0.05	(0.01)	0.002
12	Data Display	0.12	(0.02)	< 0.001
13	Data Display	0.18	(0.02)	< 0.001
14	Data Display	0.13	(0.02)	< 0.001
15	Number	0.17	(0.02)	< 0.001
16	Number	0.27	(0.02)	< 0.001
17	Number	0.15	(0.02)	< 0.001
18	Number	0.19	(0.02)	< 0.001
19	Data Display	0.23	(0.02)	< 0.001
20	Data Display	0.11	(0.02)	< 0.001
21	Number	0.16	(0.02)	< 0.001
22	Geometric Shapes and Measures	0.07	(0.01)	< 0.001
23	Number	0.23	(0.02)	< 0.001
24	Geometric Shapes and Measures	0.09	(0.02)	< 0.001
25	Data Display	0.23	(0.02)	< 0.001

Note: Values represent regression coefficient (l_j) in the covariate model affecting items; values in parenthesis represent standard errors.

Table A3. Recovery of attribute prevalence (posterior) and proportion of correct classification

Model	Attribute	5 attributes								7 attributes							
		% Bias in attribute prevalence				Proportion correctly classified				% Bias in attribute prevalence				Proportion correctly classified			
		n=500	n=1,000	n=2,000	n=5,000	n=500	n=1,000	n=2,000	n=5,000	n=500	n=1,000	n=2,000	n=5,000	n=500	n=1,000	n=2,000	n=5,000
RDINA	1	0.3%	0.3%	0.4%	0.2%	0.956	0.955	0.955	0.955	0.6%	0.4%	0.2%	0.5%	0.962	0.961	0.962	0.961
	2	0.9%	0.8%	0.7%	0.2%	0.911	0.911	0.913	0.915	1.8%	0.9%	0.6%	0.1%	0.835	0.837	0.841	0.840
	3	2.2%	0.8%	0.7%	0.3%	0.925	0.936	0.936	0.939	1.1%	0.3%	0.4%	0.1%	0.973	0.976	0.979	0.980
	4	0.0%	0.8%	0.6%	0.3%	0.886	0.885	0.883	0.880	6.2%	3.0%	1.5%	1.1%	0.913	0.937	0.951	0.962
	5	0.6%	0.9%	0.3%	0.3%	0.871	0.868	0.871	0.870	1.8%	1.3%	0.0%	0.5%	0.894	0.886	0.886	0.883
	6									1.1%	0.7%	0.1%	0.0%	0.897	0.902	0.900	0.899
	7									1.6%	0.7%	0.5%	0.4%	0.874	0.876	0.879	0.880
RDINA with covariate affecting attributes	1	1.7%	0.6%	0.8%	0.4%	0.957	0.955	0.956	0.955	2.8%	0.6%	0.4%	0.6%	0.966	0.964	0.964	0.964
	2	2.1%	0.4%	0.5%	0.5%	0.896	0.897	0.898	0.896	1.2%	0.2%	0.3%	0.4%	0.875	0.877	0.874	0.873
	3	2.2%	1.5%	1.0%	0.7%	0.870	0.864	0.865	0.861	0.9%	0.8%	0.7%	0.4%	0.920	0.919	0.914	0.915
	4	1.7%	0.4%	0.8%	0.1%	0.889	0.885	0.885	0.883	3.6%	3.0%	0.6%	0.5%	0.881	0.883	0.896	0.893
	5	3.1%	0.6%	0.0%	0.3%	0.821	0.820	0.818	0.819	2.2%	0.5%	0.6%	0.2%	0.903	0.894	0.893	0.891
	6									4.1%	2.3%	1.1%	1.2%	0.863	0.856	0.854	0.855
	7									2.2%	0.4%	0.5%	0.5%	0.828	0.820	0.815	0.815
RDINA with covariate affecting items	1	0.4%	0.9%	0.4%	0.0%	0.910	0.909	0.908	0.907	0.2%	0.5%	0.2%	0.0%	0.916	0.915	0.914	0.914
	2	0.9%	1.3%	0.4%	0.2%	0.904	0.902	0.908	0.909	5.4%	2.6%	2.2%	2.4%	0.813	0.822	0.823	0.822
	3	0.1%	1.3%	0.2%	1.0%	0.814	0.813	0.805	0.808	3.2%	2.0%	1.3%	1.2%	0.956	0.967	0.974	0.974
	4	0.5%	0.3%	0.7%	0.2%	0.864	0.862	0.861	0.856	14.2%	7.3%	3.2%	1.5%	0.820	0.869	0.903	0.903
	5	1.2%	0.3%	0.8%	0.3%	0.822	0.826	0.820	0.823	2.4%	0.9%	0.6%	0.5%	0.852	0.852	0.855	0.855
	6									0.4%	1.4%	1.4%	1.4%	0.799	0.798	0.795	0.798
	7									0.2%	1.0%	0.1%	0.1%	0.835	0.829	0.832	0.833

Note: % bias of attribute prevalence was based on maximum posterior probability classification. Proportion correctly classified is the proportion of accurate classification between generated values and the estimated data.

Table A4. Cross fitting of simulated data to other models

Number of attributes	Data fit	Statistics	Data generating conditions							
			Covariate affecting attributes				Covariate affecting items			
			n=500	*n*=1,000	*n*=2,000	*n*=5,000	*n*=500	*n*=1,000	*n*=2,000	*n*=5,000
5	RDINA	AIC	14,217.333	28,448.546	56,800.598	141,897.125	14,162.934	28,300.858	56,561.783	141,233.058
		BIC	14,449.010	28,718.472	57,108.647	142,255.570	14,394.695	28,570.784	56,869.832	141,591.504
		P_c	0.879	0.878	0.879	0.877	0.905	0.905	0.907	0.906
		% Bias	18.5%	18.3%	17.0%	16.1%	54.4%	54.0%	53.4%	53.5%
	RDINA with covariate affecting attribute	AIC	**13,869.198**	**27,711.928**	**55,299.119**	**138,148.913**	13,826.206	27,585.635	55,119.607	137,629.620
		BIC	**14,122.032**	**28,006.393**	**55,635.173**	**138,539.944**	14,079.083	27,880.100	55,455.661	138,020.651
		P_c	**0.886**	**0.884**	**0.884**	**0.883**	0.896	0.890	0.888	0.889
		% Bias	**2.9%**	**2.1%**	**1.4%**	**1.5%**	102.8%	102.1%	102.3%	102.2%
	RDINA with covariate affecting item	AIC	14,044.756	28,055.707	55,986.457	139,830.978	**13,572.316**	**27,032.238**	**54,001.861**	**134,806.385**
		BIC	14,381.546	28,448.279	56,434.529	140,352.353	**13,909.021**	**27,424.810**	**54,449.933**	**135,327.760**
		Pc	0.853	0.854	0.855	0.855	**0.856**	**0.859**	**0.859**	**0.859**
		% Bias	305.6%	309.0%	310.4%	310.7%	**3.5%**	**2.8%**	**1.5%**	**1.0%**
7	RDINA	AIC	14,193.256	28,380.323	56,712.931	141698.0851	14,155.259	28,279.772	56,579.256	141,272.726
		BIC	14,433.404	28,660.065	57,032.182	142069.5651	14,395.491	28,559.514	56,898.508	141,644.206
		P_c	0.883	0.886	0.886	0.886	0.905	0.911	0.909	0.910
		% Bias	25.4%	24.4%	23.9%	23.4%	53.1%	52.0%	51.5%	51.5%
	RDINA with covariate affecting attribute	AIC	**13,837.944**	**27,623.109**	**55,193.367**	**137,894.602**	13,812.897	27,543.098	55,094.384	137589.4807
		BIC	**14,107.595**	**27,937.205**	**55,551.825**	**138,311.702**	14,082.632	27,857.195	55,452.841	138006.581
		Pc	**0.888**	**0.888**	**0.887**	**0.888**	0.888	0.884	0.880	0.880
		% Bias	**4.1%**	**2.3%**	**1.7%**	**0.8%**	87.3%	87.6%	87.5%	86.8%
	RDINA with covariate affecting item	AIC	14,013.348	27,964.869	55,857.294	139,532.904	**13,565.900**	**27,010.677**	**54,019.263**	**134,861.099**
		BIC	14,358.566	28,367.305	56,316.568	140,067.314	**13,911.118**	**27,413.015**	**54,478.537**	**135,395.509**
		P_c	0.852	0.857	0.862	0.862	**0.859**	**0.867**	**0.868**	**0.868**
		% Bias	132.8%	135.9%	136.9%	137.2%	**4.4%**	**2.4%**	**1.7%**	**0.9%**

Note: Results indicate model fit indices (AIC and BIC), proportion correctly classified latent classes (P_c), and % bias in the item and attribute parameters. Data were generated using the two covariate RDINA models (covariate affecting attributes or items) and fit using RDINA, RDINA with covariate affecting attribute, and RDINA with covariate affecting item models for sample sizes of 500, 1000, 2000, and 5000. Results of the correct model fit were bolded.

Appendix: Syntax for fitting the covariate RDINA model in Latent GOLD

Variables
independent covariate;
dependent
      i1 cumlogit, i2 cumlogit, i3 cumlogit,   i4 cumlogit, i5 cumlogit,
      i6 cumlogit, i7 cumlogit, i8 cumlogit,   i9 cumlogit, i10 cumlogit,
      i11 cumlogit, i12 cumlogit, i13 cumlogit, i14 cumlogit, i15 cumlogit,
      i16 cumlogit, i16 cumlogit, i17 cumlogit, i18 cumlogit, i19 cumlogit,
      i21 cumlogit, i22 cumlogit, i23 cumlogit, i24 cumlogit, i25 cumlogit;
latent
      a1 ordinal 2 score = (0 1), a2 ordinal 2 score = (0 1), a3 ordinal 2 score = (0 1),
      a4 ordinal 2 score = (0 1), a5 ordinal 2 score = (0 1), a6 ordinal 2 score = (0 1),
      a7 ordinal 2 score = (0 1);
equations
      a1-a7 <- 1+ covariate;
      i1 <- 1 + a1 + covariate;
      i2 <- 1 + a2 + covariate;
      i3 <- 1 + a1 a2 + covariate;
      i4 <- 1 + a1 a2 + covariate;
      i5 <- 1 + a1 a3 + covariate;
      i6 <- 1 + a5 a6 + covariate;
      i7 <- 1 + a4 a5 a6 + covariate;
      i8 <- 1 + a1 a5 + covariate;
      i9 <- 1 + a5 + covariate;
      i10 <- 1 + a4 a5 + covariate;
      i11 <- 1 + a1 a4 + covariate;
      i12 <- 1 + a1 a7 + covariate;
      i13 <- 1 + a1 a7 + covariate;
      i14 <- 1 + a1 a2 a7 + covariate;
      i15 <- 1 + a1 + covariate;
      i16 <- 1 + a1 + covariate;
      i17 <- 1 + a1 a3 + covariate;
      i18 <- 1 + a1 a3 + covariate;
      i19 <- 1 + a1 a7 + covariate;
      i20 <- 1 + a1 a3 a7 + covariate;
      i21 <- 1 + a1 a3 + covariate;
      i22 <- 1 + a5 a6 + covariate;
      i23 <- 1 + a1 + covariate;
      i24 <- 1 + a5 + covariate;
      i25 <- 1 + a1 a7 + covariate;
end model

Note: The covariate can be added at the item or attribute level, depending on the model specified. Users should reference the Latent Gold syntax and technical manuals for optimal starting values and estimation methods.