

Supplemental Material

CBE—Life Sciences Education

Peffer *et al.*

Supplemental Table 1. Nature of science items included in this study

<i>Item</i>	<i>Source</i>
<i>It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?</i>	VNOS; Lederman et al. 2002
<i>After scientists have developed a scientific theory (e. g., atomic theory, evolution theory), does the theory ever change? Explain why and defend your answer with examples.</i>	VNOS; Lederman et al. 2002
<i>Do you think that scientific investigations can follow more than one method? Explain why and defend your answer with examples.</i>	VASI; Lederman et al. 2014

Supplemental Table 2. Analysis of maximum likelihood parameter estimates of Poisson regression model for total number of actions. **Bold font indicates statistical significance.**

Analysis Of Maximum Likelihood Parameter Estimates							
Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits	Wald Chi-Square	Pr >	ChiSq
Intercept	1	4.2269	0.3860	3.4703 4.9835	119.91	<.0001	
Non-science Major	1	-0.4492	0.1647	-0.7721 -0.1263	7.43	0.0064	
Biology Major	1	-0.2030	0.1560	-0.5087 0.1027	1.69	0.1931	
Biology Graduate	0	0.0000	0.0000	0.0000 0.0000	.	.	
Intrinsic Goal Regulation	1	0.0161	0.0544	-0.0904 0.1227	0.09	0.7667	
Extrinsic Goal Regulation	1	-0.0810	0.0445	-0.1682 0.0062	3.31	0.0687	
Task Value	1	-0.0228	0.0628	-0.1459 0.1002	0.13	0.7162	
Control Beliefs	1	-0.0605	0.0543	-0.1669 0.0460	1.24	0.2655	
Self-Efficacy	1	0.0147	0.0627	-0.1082 0.1377	0.06	0.8145	
Test Anxiety	1	-0.0072	0.0335	-0.0729 0.0584	0.05	0.8295	
Rehearsal	1	-0.0121	0.0452	-0.1006 0.0765	0.07	0.7895	
Elaboration	1	-0.0462	0.0581	-0.1600 0.0676	0.63	0.4262	
Organization	1	-0.0382	0.0476	-0.1315 0.0551	0.64	0.4227	
Critical Thinking	1	-0.1222	0.0421	-0.2048 -0.0397	8.42	0.0037	
Metacognition	1	0.1744	0.0697	0.0378 0.3110	6.26	0.0124	
Time and Study Environment	1	-0.3035	0.0567	-0.4147 -0.1924	28.65	<.0001	
Effort Regulation	1	0.1492	0.0650	0.0219 0.2766	5.27	0.0216	
Peer Learning	1	-0.0674	0.0369	-0.1398 0.0050	3.33	0.0680	
Help Seeking	1	-0.0119	0.0412	-0.0926 0.0688	0.08	0.7725	
Science Identity	1	0.1865	0.0740	0.0414 0.3316	6.34	0.0118	
NOS1_Sophisticated	1	0.2899	0.2507	-0.2014 0.7812	1.34	0.2474	
NOS1_Mixed	1	0.0874	0.0977	-0.1040 0.2788	0.80	0.3709	
NOS1_Naive	0	0.0000	0.0000	0.0000 0.0000	.	.	

Analysis Of Maximum Likelihood Parameter Estimates							
Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits		Wald Chi-Square	Pr > ChiSq
NOS2_Sophisticated	1	0.4031	0.1197	0.1685	0.6377	11.34	0.0008
NOS2_Mixed	1	0.0546	0.1052	-0.1516	0.2607	0.27	0.6038
NOS2_Naive	0	0.0000	0.0000	0.0000	0.0000	.	.
Race_White/European American	1	-0.2386	0.1072	-0.4487	-0.0286	4.96	0.0260
Race_Hispanic/Latin American	1	-0.1944	0.1409	-0.4706	0.0818	1.90	0.1678
Race_Other	0	0.0000	0.0000	0.0000	0.0000	.	.
Gender_Male	1	-0.3124	0.1057	-0.5196	-0.1052	8.73	0.0031
Gender_Female	0	0.0000	0.0000	0.0000	0.0000	.	.
No hypothesis revision	1	-0.2091	0.0960	-0.3973	-0.0209	4.74	0.0294
Hypothesis revision	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale	0	1.0000	0.0000	1.0000	1.0000		

Supplemental Table 3. Analysis of maximum likelihood parameter estimates of Poisson regression model for number of actions before generation of first hypothesis. **Bold font indicates statistical significance.**

Analysis Of Maximum Likelihood Parameter Estimates							
Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits		Wald Chi-Square	Pr > ChiSq
Intercept	1	2.6384	0.8429	0.9862	4.2905	9.80	0.0017
Non-science Major	1	0.8156	0.3338	0.1615	1.4698	5.97	0.0145
Biology Major	1	0.5574	0.3541	-0.1366	1.2515	2.48	0.1154
Biology Graduate	0	0.0000	0.0000	0.0000	0.0000	.	.
Intrinsic Goal Regulation	1	-0.1346	0.1026	-0.3356	0.0664	1.72	0.1894
Extrinsic Goal Regulation	1	-0.5776	0.1023	-0.7780	-0.3771	31.90	<.0001
Task Value	1	-0.0230	0.1233	-0.2647	0.2187	0.03	0.8521
Control Beliefs	1	-0.2070	0.1302	-0.4621	0.0481	2.53	0.1117
Self-Efficacy	1	0.0743	0.1392	-0.1984	0.3471	0.29	0.5932
Test Anxiety	1	0.0941	0.0735	-0.0500	0.2381	1.64	0.2006
Rehearsal	1	-0.0706	0.0988	-0.2643	0.1230	0.51	0.4747
Elaboration	1	0.3326	0.1202	0.0970	0.5681	7.66	0.0057
Organization	1	0.0383	0.0989	-0.1556	0.2322	0.15	0.6986
Critical Thinking	1	-0.1775	0.0963	-0.3662	0.0112	3.40	0.0652
Metacognition	1	0.0142	0.1431	-0.2663	0.2946	0.01	0.9210
Time Study Environment	1	-0.3675	0.1364	-0.6348	-0.1002	7.26	0.0070
Effort Regulation	1	0.1985	0.1437	-0.0831	0.4801	1.91	0.1672
Peer Learning	1	-0.3237	0.0928	-0.5056	-0.1418	12.17	0.0005
Help Seeking	1	0.1189	0.0875	-0.0526	0.2904	1.85	0.1742
Science Identity	1	0.7498	0.1612	0.4339	1.0657	21.64	<.0001
NOS1_Sophisticated	1	1.1630	0.4610	0.2595	2.0666	6.36	0.0116
NOS1_Mixed	1	0.4001	0.2218	-0.0345	0.8348	3.26	0.0712

Analysis Of Maximum Likelihood Parameter Estimates							
Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits		Wald Chi-Square	Pr > ChiSq
NOS1_Naive	0	0.0000	0.0000	0.0000	0.0000	.	.
NOS2_Sophisticated	1	1.1398	0.2863	0.5786	1.7010	15.85	<.0001
NOS2_Mixed	1	0.6384	0.2715	0.1062	1.1706	5.53	0.0187
NOS2_Naive	0	0.0000	0.0000	0.0000	0.0000	.	.
Race_White/European American	1	-1.2317	0.2447	-1.7113	-0.7521	25.34	<.0001
Race_Hispanic/Latin American	1	-0.2484	0.2743	-0.7859	0.2892	0.82	0.3651
Race_Other	0	0.0000	0.0000	0.0000	0.0000	.	.
Gender_Male	1	-1.4068	0.2755	-1.9468	-0.8668	26.07	<.0001
Gender_Female	0	0.0000	0.0000	0.0000	0.0000	.	.
No hypothesis revision	1	0.2801	0.2465	-0.2030	0.7632	1.29	0.2559
Hypothesis revision	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale	0	1.0000	0.0000	1.0000	1.0000		

Supplemental Table 4. Analysis of maximum likelihood estimates for logistic regression of complexity. **Bold font indicates statistical significance.**

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-0.8655	4.7951	0.0326	0.8568
Non-science Major	1	0.0579	1.9901	0.0008	0.9768
Biology Major	1	-0.6052	1.6086	0.1415	0.7068
Intrinsic Goal Regulation	1	-0.3172	0.7388	0.1843	0.6677
Extrinsic Goal Regulation	1	0.3086	0.4422	0.4870	0.4853
Task Value	1	0.2176	0.7888	0.0761	0.7826
Control Beliefs	1	-1.3490	0.5968	5.1093	0.0238
Self-Efficacy	1	1.4846	0.6291	5.5698	0.0183
Test Anxiety	1	0.0330	0.3502	0.0089	0.9248
Rehearsal	1	0.7751	0.5226	2.1996	0.1380
Elaboration	1	0.7516	0.6176	1.4810	0.2236
Organization	1	0.2031	0.4594	0.1953	0.6585
Critical Thinking	1	0.6191	0.4465	1.9224	0.1656
Metacognition	1	-1.7781	0.8773	4.1078	0.0427
Time and Study Environment	1	1.2463	0.6470	3.7104	0.0541
Effort Regulation	1	-1.5017	0.6216	5.8355	0.0157
Peer Learning	1	-0.5352	0.3901	1.8824	0.1701
Help Seeking	1	1.2058	0.5088	5.6166	0.0178
Science Identity	1	-2.3117	0.8507	7.3850	0.0066
NOS Principle 1_Sophisticated	1	4.6262	2.6294	3.0955	0.0785
NOS Principle 2_Mixed	1	0.4361	0.9070	0.2312	0.6306
NOS Principle	1	-1.8985	1.2954	2.1478	0.1428

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
2_Sophisticated					
NOS Principle 2_Mixed	1	-1.3205	1.0153	1.6916	0.1934
Race_White/European American	1	0.8927	1.0163	0.7716	0.3797
Race_Hispanic/Latin American	1	0.8706	1.4298	0.3708	0.5426
Gender	1	-1.2470	1.1223	1.2346	0.2665
Hypothesis Revision	1	1.3084	1.0903	1.4401	0.2301

Supplemental Table 5. Analysis of maximum likelihood estimates for logistic regression of complexity with 11 predictors. **Bold font indicates statistical significance.**

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	0.4211	2.8515	0.0218	0.8826
Control Beliefs	1	-1.2255	0.4878	6.3117	0.0120
Self-Efficacy	1	1.1055	0.4462	6.1388	0.0132
Rehearsal	1	1.0086	0.4481	5.0656	0.0244
Elaboration	1	0.6790	0.4074	2.7771	0.0956
Metacognition	1	-1.6249	0.7718	4.4321	0.0353
Time and Study Environment	1	1.1611	0.5059	5.2673	0.0217
Effort Regulation	1	-1.1282	0.4568	6.0998	0.0135
Help Seeking	1	0.6449	0.3231	3.9834	0.0460
Science Identity	1	-2.0102	0.5390	13.9068	0.0002
NOS Principle 1_Sophisticated	1	5.4477	2.3388	5.4255	0.0198
NOS Principle 1_Mixed	1	0.2721	0.7313	0.1385	0.7098
Hypothesis Revision	1	1.9165	0.9317	4.2310	0.0397

Supplementary Table 6. Analysis of maximum likelihood parameter estimates of multinomial logistic regression model for predicting how likely individuals are to be in one of three activity-based clusters. **Bold font indicates statistical significance.**

Analysis of Maximum Likelihood Estimates						
Parameter	Combined	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	1	-2.0386	4.6512	0.1921	0.6612
Intercept	2	1	-2.9917	4.3480	0.4734	0.4914
Intrinsic Goal Regulation	1	1	2.0949	0.8848	5.6052	0.0179
Intrinsic Goal Regulation	2	1	0.1722	0.6797	0.0642	0.7999
Extrinsic Goal Regulation	1	1	1.9619	0.6419	9.3413	0.0022
Extrinsic Goal Regulation	2	1	0.7311	0.4672	2.4493	0.1176
Task Value	1	1	-1.7916	0.9084	3.8903	0.0486
Task Value	2	1	-0.7007	0.6731	1.0840	0.2978
Control Beliefs	1	1	-0.7868	0.6290	1.5649	0.2109
Control Beliefs	2	1	-0.2264	0.5815	0.1515	0.6971
Self-Efficacy	1	1	-0.6091	0.6432	0.8968	0.3436
Self-Efficacy	2	1	-0.5878	0.6453	0.8297	0.3624
Test Anxiety	1	1	-0.7357	0.4285	2.9483	0.0860
Test Anxiety	2	1	-0.2592	0.3094	0.7015	0.4023
Rehearsal	1	1	-0.3590	0.5238	0.4697	0.4931
Rehearsal	2	1	0.2311	0.4519	0.2615	0.6091
Elaboration	1	1	-0.2681	0.6842	0.1535	0.6952
Elaboration	2	1	-0.1583	0.5965	0.0704	0.7907
Organization	1	1	0.4196	0.5039	0.6932	0.4051
Organization	2	1	0.2512	0.4508	0.3106	0.5773
Critical Thinking	1	1	-0.8925	0.5056	3.1158	0.0775
Critical Thinking	2	1	0.1975	0.4806	0.1689	0.6811

Analysis of Maximum Likelihood Estimates

Parameter	Combined	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Metacognition	1	1	2.0104	0.9218	4.7563	0.0292
Metacognition	2	1	1.4185	0.8237	2.9658	0.0850
Time and Study Environment	1	1	1.8435	0.8066	5.2237	0.0223
Time and Study Environment	2	1	0.3110	0.5928	0.2751	0.5999
Effort Regulation	1	1	-1.6121	0.7494	4.6277	0.0315
Effort Regulation	2	1	-0.3221	0.6004	0.2879	0.5916
Peer Learning	1	1	0.8779	0.4827	3.3074	0.0690
Peer Learning	2	1	0.0680	0.4089	0.0276	0.8680
Help Seeking	1	1	-1.2710	0.5751	4.8842	0.0271
Help Seeking	2	1	-0.5057	0.4506	1.2597	0.2617
Science Identity	1	1	-1.1288	0.8721	1.6753	0.1955
Science Identity	2	1	-1.2858	0.7374	3.0406	0.0812
Gender_Male	1	1	6.3248	1.7738	12.7137	0.0004
Gender_Male	2	1	4.5949	1.4542	9.9838	0.0016
Race_White/European American	1	1	3.4846	1.2588	7.6633	0.0056
Race_White/European American	2	1	2.9683	1.0988	7.2975	0.0069
Race_Hispanic/Latin American	1	1	2.4080	1.4406	2.7939	0.0946
Race_Hispanic/Latin American	2	1	1.2998	1.2745	1.0402	0.3078
Hypothesis Revision	1	1	-1.2045	1.2499	0.9286	0.3352
Hypothesis Revision	2	1	0.9910	1.2746	0.6045	0.4369
Non-science Major	1	1	-4.7288	2.0794	5.1714	0.0230
Non-science Major	2	1	-1.2973	1.9815	0.4286	0.5127
Biology Major	1	1	-1.2306	1.6801	0.5365	0.4639

Analysis of Maximum Likelihood Estimates

Parameter	Combined	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Biology Major	2	1	-0.0666	1.9811	0.0011	0.9732