Supplemental Material

CBE—Life Sciences Education

Perera *et al.*

Supplemental Material

Students in fully-online programs report more positive attitudes toward science than students in traditional, in-person programs

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Table S1: Factor analysis of the difference between the pre- and post-course responses to the 21 Science Attitudes items with corresponding eigenvalues shown (loadings of 0.5 or greater are shown in bold).

Science Attitudes Item	Factor 1	Factor 2
All valid	0.24	0.20
Creativity	**0.77**	-0.16
Experience	0.30	0.16
Just tell	**0.68**	-0.10
Missing facts	0.11	0.24
No major	**0.66**	-0.11
Not connected	**0.76**	-0.16
Satisfaction	-0.18	**0.60**
Think skills	-0.22	**0.64**
True	0.09	0.43
Do well	-0.17	**0.64**
Experiment fail	0.27	0.10
Explain	-0.20	**0.62**
Facts	0.27	0.21
Figure out	**0.60**	-0.09
Know before	**0.66**	-0.01
Lab confirm	0.20	0.42
Only experts	**0.62**	-0.08
Statistics	**0.53**	0.08
Straight line	0.37	0.16
Work ourselves	0.03	0.39

Table S2: Factor analysis of the post-course responses to the 11 Benefits items with corresponding eigenvalues shown.

Benefits Item	Factor Loading
Analyze	0.91
Demanding	0.88
Evidence	0.88
Integrate	0.90
Interpret	0.83
Knowledge construction	0.91
Obstacle tolerance	0.87
Real scientists	0.88
Independence	0.74
Science	0.83
Scientists think	0.85

Table S3: Simultaneous linear regression models for predicting the post-course *SS* factor scores (SS models) and *PV* factor scores (PV models) of the whole cohort. The reference groups for the categorical variables gender (female or male) and program type (*i-course* or *o-course*) were female and *i-course*. Listed are standardized coefficients (i.e. continuous variables were scaled and centered prior to the regression). Statistical significance (i.e. $p < 0.05$) is indicated with highlighting. The Studentized Breusch-Pagan test was used to test for heteroscedasticity (when heteroscedasticity is present the p-values are marked in bold red text).

Model SS1		
Variable	**Coefficient**	**p-value**
(Intercept)	$2.783 \cdot 10^{-16}$	1
SS Factor (pre-course)	$4.968 \cdot 10^{-1}$	< 0.001

Adjusted $R^2 = 0.2451$
F-statistic = 147.1 on 1 and 449 DF with $p < 0.001$
BP = 0.3275, df = 1, p-value = 0.57

Model PV1		
Variable	**Coefficient**	**p-value**
(Intercept)	$5.154 \cdot 10^{-16}$	1
PV Factor (pre-course)	$4.869 \cdot 10^{-1}$	< 0.001

Adjusted $R^2 = 0.2354$
F-statistic = 139.5 on 1 and 449 DF with $p < 0.001$
BP = 3.9901, df = 1, p-value = **0.0458**

Model SS3		
Variable	**Coefficient**	**p-value**
(Intercept)	-0.16026	0.024
SS Factor (pre-course)	0.45629	< 0.001
Program type	0.30210	< 0.001
Gender	0.02819	0.73

Adjusted $R^2 = 0.263$
F-statistic = 54.54 on 3 and 447 DF with $p < 0.001$
BP = 1.4596, df = 3, p-value = 0.69

Model PV3		
Variable	**Coefficient**	**p-value**
(Intercept)	-0.22015	0.00205
PV Factor (pre-course)	0.45890	< 0.001
Program type	0.29221	< 0.001
Gender	0.16264	0.0497

Adjusted $R^2 = 0.258$
F-statistic = 53.16 on 3 and 447 DF with $p < 0.001$
BP = 9.8755, df = 3, p-value = **0.0197**

Model SS4		
Variable	**Coefficient**	**p-value**
(Intercept)	-0.15245	< 0.01
SS Factor (pre-course)	0.43097	< 0.001
Program type	0.29665	< 0.001
SS Factor (pre-course) X Program type	0.06335	0.46

Adjusted $R^2 = 0.264$
F-statistic = 54.74 on 3 and 447 DF with $p < 0.001$
BP = 1.6136, df = 3, p-value = 0.66

Model PV4		
Variable	**Coefficient**	**p-value**
(Intercept)	-0.13164	0.0212
PV Factor (pre-course)	0.52146	< 0.001
Program type	0.28161	< 0.001
PV Factor (pre-course) X Program type	-0.10730	0.19

Adjusted $R^2 = 0.254$
F-statistic = 52.19 on 3 and 447 DF with $p < 0.001$
BP = 5.3961, df = 3, p-value = 0.145

Table S4: Logistic regression models for predicting course grade of the whole cohort. Binary dependent variable was whether (1) or not (0) a student received an *A* for their course grade. The reference groups for the categorical variables gender (female or male) and program type (*i-course* or *o-course*) were female and *i-course*. Listed are standardized coefficients (i.e. continuous variables were scaled and centered prior to the regression). Statistical significance (i.e. $p < 0.05$) is indicated with highlighting.

Model GA1		
Variable	**Coefficient**	**p-value**
(Intercept)	0.58702	< 0.001
SS Factor (pre-course)	0.00738	0.96
Program Type	-0.01455	0.94
SS Factor (pre) X Program Type	0.44155	0.038

Model GA2		
Variable	**Coefficient**	**p-value**
(Intercept)	0.580112	< 0.001
SS Factor (pre) X *i-course*	0.005799	0.96
SS Factor (pre) X *o-course*	0.447192	< 0.01

Model GA3		
Variable	**Coefficient**	**p-value**
(Intercept)	0.7926	< 0.001
University GPA	1.4777	< 0.001

Model GA4		
Variable	**Coefficient**	**p-value**
(Intercept)	0.3102	0.019
Gender	0.6983	< 0.001

Model GA5		
Variable	**Coefficient**	**p-value**
(Intercept)	0.3712	0.0196
University GPA	1.5372	< 0.001
Gender	0.9493	< 0.001

Model GA6		
Variable	**Coefficient**	**p-value**
(Intercept)	0.2519	0.203
University GPA	1.5409	< 0.001
Gender	0.9839	< 0.001
Program Type	0.2469	0.32

Model GA7		
Variable	**Coefficient**	**p-value**
(Intercept)	0.4136	0.0111
University GPA	1.5396	< 0.001
Gender	0.9125	< 0.001
SS Factor (pre-course)	0.1403	0.26
PV Factor (pre-course)	0.1072	0.42

Model GA8		
Variable	**Coefficient**	**p-value**
(Intercept)	0.3302	0.11
University GPA	1.5422	< 0.001
Gender	0.9358	< 0.001
SS Factor (pre-course)	0.1193	0.35
PV Factor (pre-course)	0.1091	0.41
Program Type	0.1690	0.51

Model GA9		
Variable	**Coefficient**	**p-value**
(Intercept)	0.27948	0.17
University GPA	1.54627	< 0.001
Gender	0.95390	< 0.001
SS Factor (pre-course)	0.03826	0.80
Program Type	0.16083	0.53
SS Factor (pre) X Program Type	0.36639	0.16

Model GA10		
Variable	**Coefficient**	**p-value**
(Intercept)	0.35852	0.0276
University GPA	1.54377	< 0.001
Gender	0.93084	< 0.001
SS Factor (pre) X *i-course*	0.05588	0.70
SS Factor (pre) X *o-course*	0.42294	0.0491

Model GA11		
Variable	**Coefficient**	**p-value**
(Intercept)	0.4002	0.0161
University GPA	1.5045	< 0.001
Gender	1.0478	< 0.001
SS Factor	0.5452	< 0.001
PV Factor	0.2505	0.09
Benefits Factor	0.1510	0.29

Model GA12		
Variable	**Coefficient**	**p-value**
(Intercept)	0.3682	0.0245
University GPA	1.4836	< 0.001
Gender	1.0346	< 0.001
SS Factor	0.5576	< 0.001

Table S5: Logistic regression models for predicting course grade of the whole cohort. Binary dependent variable was whether (1) or not (0) a student received a failing course grade. The reference groups for the categorical variables gender (female or male) and program type (*i-course* or *o-course*) were female and *i-course*. Listed are standardized coefficients (i.e. continuous variables were scaled and centered prior to the regression). Statistical significance (i.e. $p < 0.05$) is indicated with highlighting.

Model GF1		
Variable	**Coefficient**	**p-value**
(Intercept)	-3.3892	< 0.001
SS Factor (pre-course)	0.7794	0.0689
Program Type	0.2831	0.5884
SS Factor (pre) X Program Type	-1.2514	0.0230

Model GF2		
Variable	**Coefficient**	**p-value**
(Intercept)	-3.2382	< 0.001
SS Factor (pre) X *i-course*	0.7189	0.0633
SS Factor (pre) X *o-course*	-0.4860	0.1813

Model GF3		
Variable	**Coefficient**	**p-value**
(Intercept)	-4.2338	< 0.001
University GPA	-1.3875	< 0.001

Model GF4		
Variable	**Coefficient**	**p-value**
(Intercept)	-2.9178	< 0.001
Gender	-0.8294	0.125

Model GF5		
Variable	**Coefficient**	**p-value**
(Intercept)	-3.8872	< 0.001
University GPA	-1.4027	< 0.001
Gender	-0.9662	0.11

Model GF6		
Variable	**Coefficient**	**p-value**
(Intercept)	-3.6419	< 0.001
University GPA	-1.5391	< 0.001
Gender	-1.0267	0.0915
Program Type	-0.7672	0.22

Model GF7		
Variable	**Coefficient**	**p-value**
(Intercept)	-4.24157	< 0.001
University GPA	-1.39034	< 0.001
SS Factor (pre-course)	0.08498	0.78
PV Factor (pre-course)	-0.11029	0.73

Model GF8		
Variable	**Coefficient**	**p-value**
(Intercept)	-4.0454	< 0.001
University GPA	-1.5084	< 0.001
SS Factor (pre-course)	0.1179	0.70
PV Factor (pre-course)	-0.1117	0.73
Program Type	-0.6838	0.27

Model GF9		
Variable	**Coefficient**	**p-value**
(Intercept)	-4.0926	< 0.001
University GPA	-1.4799	< 0.001
SS Factor (pre-course)	0.6573	0.15
Program Type	-0.5613	0.38
SS Factor (pre) X Program Type	-1.0669	0.0684

Model GF10		
Variable	**Coefficient**	**p-value**
(Intercept)	-4.2725	< 0.001
University GPA	-1.3833	< 0.001
SS Factor (pre) X *i-course*	0.7760	0.10
SS Factor (pre) X *o-course*	-0.3866	0.27

Model GF11		
Variable	**Coefficient**	**p-value**
(Intercept)	-4.5833	< 0.001
University GPA	-1.4074	< 0.001
SS Factor	-0.5402	0.012
PV Factor	-0.4041	0.18
Benefits Factor	0.2256	0.57

Model GF12		
Variable	**Coefficient**	**p-value**
(Intercept)	-4.5184	< 0.001
University GPA	-1.4315	< 0.001
SS Factor	-0.5105	0.0148

Table S6: Unpaired and unpublished CURE benchmark data for the Science Attitudes items (aggregate of over 5,000 students from the 2014-2015 academic year).

	Pre-course		Post-course		Change	
Item Label	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Factor**
No major	3.74	1.03	3.54	1.19	-0.20	*Scientific Sophistication (SS)*[+]
Figure out	3.32	0.91	3.23	1.02	-0.09	
Just tell	3.14	1.09	3.15	1.15	0.01	
Creativity	4.11	0.90	3.97	1.04	-0.14	
Not connected	4.00	0.94	3.85	1.07	-0.15	
Only experts	3.59	0.89	3.49	0.99	-0.10	
Know before	4.02	0.87	3.90	1.02	-0.12	
Statistics	3.16	1.01	3.21	1.10	0.05	
Thinking skills	4.10	0.74	4.07	0.92	-0.03	*Personal Value (PV)*
Satisfaction	4.23	0.77	4.12	0.95	-0.11	
Do well	4.01	0.75	3.90	0.92	-0.11	
Explain	4.09	0.81	4.01	0.92	-0.08	
True	3.35	0.87	3.28	0.98	-0.07	None
Experience	2.99	0.89	3.08	1.03	0.09	
Missing facts	2.95	0.97	3.00	1.04	0.05	
All valid	2.60	1.01	2.68	1.09	0.08	
Facts	3.11	0.97	3.10	1.04	-0.01	
Experiment fail	1.86	0.86	1.92	1.02	0.06	
Straight line	3.05	0.90	3.22	0.98	0.17	
Work ourselves	3.26	0.95	3.35	1.00	0.09	
Lab confirm	3.72	0.81	3.59	0.98	-0.13	
Write	3.94	0.73	3.86	0.90	-0.08	Excluded

[+]Items in this factor are reverse scored

Benchmark Cronbach Alpha values for the 22 Science Attitudes items:
Pre-course = 0.72
Post-course = 0.87

This benchmark data does not include the results of this work.

Table S7: Unpaired and unpublished CURE benchmark data for the Benefits items (aggregate of over 5,000 students from the 2014-2015 academic year)

Item Label	Mean	Std. Dev.	Factor
Interpret	3.52	1.04	*Benefits*
Obstacle tolerance	3.49	1.05	
Demanding	3.40	1.09	
Knowledge construction	3.41	1.06	
Integrate	3.44	1.05	
Real scientists	3.57	1.08	
Evidence	3.62	1.07	
Analyze	3.72	1.02	
Science	3.57	1.07	
Scientists think	3.39	1.10	
Independence	3.33	1.16	
Career	2.94	1.24	Excluded
Your field	3.44	1.12	
Ethical	3.11	1.22	
Lab techniques	3.73	1.10	
Self confidence	3.18	1.23	
Learning community	3.44	1.14	
Teacher	2.90	1.27	
Primary literature	3.32	1.17	
Oral	3.10	1.25	
Writing	3.29	1.18	

Table S8: Science Attitudes and Benefits factor scores by degree program type along with CURE benchmark data.

		Mean Values[1]		
	Factor	**Pre-course**	**Post-course**	**Change[2]**
Full cohort (n = 451)	***SS***	3.74	3.59	-0.16**
	PV	3.94	4.05	0.11***
	Benefits	--	3.69	--
***o-course* students (n_o = 219)**	***SS***	3.91	3.83	-0.08
	PV	4.00	4.19	0.19***
	Benefits	--	3.92	--
***i-course* students (n_i = 232)**	***SS***	3.58	3.35	-0.23***
	PV	3.89	3.92	0.03
	Benefits	--	3.48	--
CURE benchmark data[3]	***SS***	3.64	3.54	-0.10
	PV	4.11	4.02	-0.09
	Benefits	--	3.50	--

[1]Significance indicators: $p < 0.05$ (*), $p < 0.01$ (**), $p < 0.001$ (***)
[2]Change calculated from paired pre- and post-course responses
[3]Unpaired pre- and post-course numbers (see **Tables S6** & **S7** above for the complete CURE benchmark dataset)