Supplemental Material

CBE—Life Sciences Education

Rodrigo-Peiris *et al.*

Supplemental online materials for *A low-intensity, hybrid design between a "traditional" and a "course-based" research experience yields positive outcomes for science undergraduate freshmen and shows potential for large-scale application*

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This supplement contains the following:

Table S1. SRE research projects in Spring 2015

STEM research discipline	Research project title
Biology - Molecular and Developmental Biology	Analysis of Gene Expression During Salamander Tail Regeneration
Biomedical Engineering	Cell Mechanobiology and Tissue Bioengineering: Pressuring Cells to Form Vessels
Biomedical Science	Cerebrovascular Aging: Micro-bleeds, Transcriptional Profiling, and *in vitro* Modeling
Chemistry	Clean Water through Chemistry
Biomedical Science	Daily Changes in Skin Temperature Inversely Correlate with Heart Rate
Biomedical Science	Drug Interactions in Breast Cancer
Biology - Animal Ecology	Ecotoxicology and Environmental Health
Biology - Cell Biology	Effect of Autophagy on Progesterone Production in Cultured Cells
Biology - Human Physiology	Meditation, Sleep, and Performance
Agriculture - Plant Biotechnology	Natural Products from Plants and their Uses
Agriculture - Plant Pathology	Novel Strategies for Biological Control of Bacterial Wilt of Cucurbits Under Organic Cultivation
Biology - Genetics	Sex, Flies, and Good Gene Hunting – Section I
Biology - Genetics	Sex, Flies, and Good Gene Hunting – Section II
Biology - Genetics	Sex, Flies, and Good Gene Hunting – Section III
Biology - Genetics	Sex, Flies, and Good Gene Hunting – Section IV
Biomedical Science	Regulation of Cardiomyocyte Calcium Homeostasis
Chemistry	Student Centered Original Research Experience (SCORE)
Biology - Plant Ecology	The Acclimating Leaf
Biomedical Science	The Role of Inflammation in Alzheimer's Disease Pathology
Environment and Earth Sciences	Tracking Contaminants in Central Kentucky Watersheds

Table S2. Details of the courses used for STEM academic performance evaluations

Course prefix and number	Department	Course title	Lecture, laboratory and/or recitation	Number of credit hours
Lower-division STEM courses				
BIO 148	Biology	INTRODUCTORY BIOLOGY I	Lecture	3
BIO 155	Biology	LABORATORY FOR INTRODUCTORY BIOLOGY I	Laboratory	1
BIO 152	Biology	PRINCIPLES OF BIOLOGY II	Lecture	3
CHE 105	Chemistry	GENERAL COLLEGE CHEMISTRY I	Lecture	4
CHE 111	Chemistry	LABORATORY TO ACCOMPANY GENERAL CHEMISTRY I	Laboratory	1
CHE 107	Chemistry	GENERAL COLLEGE CHEMISTRY II	Lecture	3
CHE 113	Chemistry	LABORATORY TO ACCOMPANY GENERAL CHEMISTRY II	Laboratory	2
MA 113	Math	113 CALCULUS I	Lecture + recitation	4
MA 137	Math	CALCULUS I WITH LIFE SCIENCE APPLICATIONS	Lecture + recitation	4
MA 114	Math	CALCULUS II	Lecture + recitation	4
MA 138	Math	MA 138 CALCULUS II WITH LIFE SCIENCE APPLICATIONS	Lecture + recitation	4
Upper-division STEM courses				
BIO 303	Biology	INTRODUCTION TO EVOLUTION	Lecture + recitation	4
BIO 304	Biology	PRINCIPLES OF GENETICS	Lecture + laboratory	4
BIO 315	Biology	INTRODUCTION TO CELL BIOLOGY	Lecture + laboratory	4
BIO 325	Biology	ECOLOGY	Lecture + laboratory	4
BIO 350	Biology	ANIMAL PHYSIOLOGY	Lecture + laboratory	4
BIO 430G	Biology	PLANT PHYSIOLOGY	Lecture + laboratory	4
CHE 230	Chemistry	ORGANIC CHEMISTRY I	Lecture	3
CHE 231	Chemistry	ORGANIC CHEMISTRY LABORATORY I	Laboratory	1
CHE 232	Chemistry	ORGANIC CHEMISTRY II	Lecture	3
PHY 211	Physics	GENERAL PHYSICS	Lecture + laboratory + recitation	5
PHY 213	Physics	GENERAL PHYSICS	Lecture + laboratory + recitation	5

Table S3. Percentage student respondents to Likert-scale survey items

Survey item from STEMCats Survey 1	Percentage of respondents (%)						
	Strongly Disagree [Likert 1]	Quite Disagree [Likert 2]	Somewhat Disagree [Likert 3]	Neither Agree nor Disagree [Likert 4]	Somewhat Agree [Likert 5]	Quite Agree [Likert 6]	Strongly Agree [Likert 7]
Authentic Research (n = 93)	1.08	1.08	3.23	2.15	19.35	35.48	37.63
Supportive Environment (n = 91)	0.00	2.20	1.10	7.69	17.58	25.27	46.15
Improved your scientific thinking (n = 90)	1.11	1.11	2.22	8.89	20.00	28.89	37.78
Improved your science/STEM knowledge (n = 90)	1.11	0.00	1.11	8.89	26.67	36.67	25.56
Improved your experimentation skills (n = 91)	0.00	2.20	2.20	4.40	19.78	32.97	38.46
Improved your comfort level with other STEM students (n = 92)	1.09	0.00	0.00	10.87	28.26	27.17	32.61
Improved your comfort-level with faculty (n = 92)	1.09	0.00	2.17	2.17	27.17	30.43	36.96
Enhanced your sense that you are part of a group (n = 91)	2.20	1.10	2.20	7.69	30.77	28.57	27.47
Enhanced your motivation/enthusiasm for STEM (n = 93)	2.15	1.08	1.08	16.13	23.66	22.58	33.33
Enhanced your motivation towards accomplishing graduation from your STEM degree (n = 91)	0.00	2.20	5.49	5.49	19.78	32.97	34.07
Enhanced your critical thinking (n = 90)	2.22	0.00	2.22	5.56	21.11	40.00	28.89
Enhanced your trouble-shooting skills (n = 90)	1.11	1.11	2.22	10.00	26.67	30.00	28.89
Enhanced your knowledge in scientific communication (n = 91)	1.10	1.10	1.10	6.59	24.18	36.26	29.67
Enhanced your teamwork skills (n = 89)	2.25	0.00	2.25	6.74	24.72	32.58	31.46
Enhanced your comfort level to work with colleagues from different academic backgrounds (e.g. different majors) (n = 89)	0.00	1.12	2.25	7.87	24.72	32.58	31.46
Improved your sense that science is connected to human lives (n = 90)	0.00	0.00	1.11	12.22	15.56	26.67	44.44
Improved your sense that science is important to resolve real world issues (n = 91)	1.10	0.00	2.20	8.79	21.98	25.27	40.66
Enhanced your motivation towards learning STEM (n = 90)	2.22	2.22	4.44	7.78	18.89	31.11	33.33
Improved your science/STEM knowledge (n = 90)	1.11	0.00	1.11	8.89	26.67	36.67	25.56
Improved your understanding of scientific concepts (n = 91)	1.10	0.00	1.10	6.59	27.47	32.97	30.77

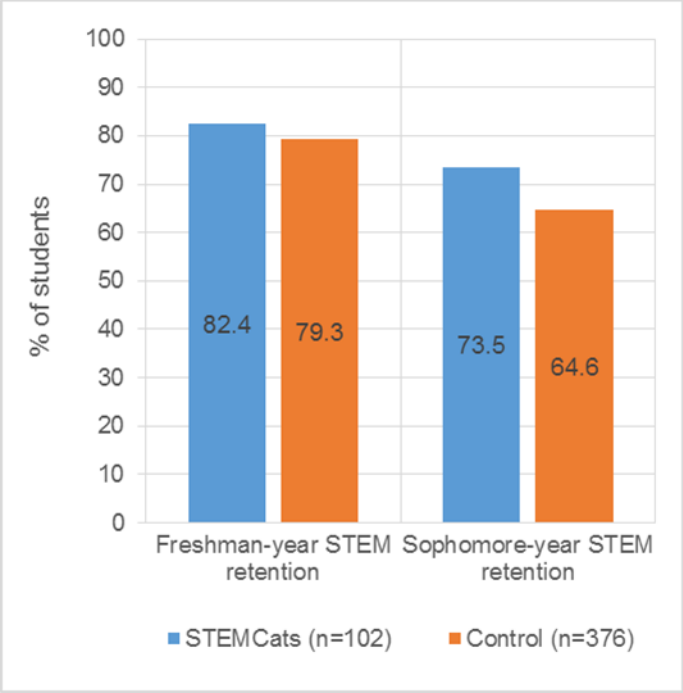

Figure S1. Descriptive data comparison for retention in a STEM major between STEMCats and non-STEMCats control. Percentage STEM retention for the freshman-year and sophomore-year are depicted. z-test for proportions between STEMCats and control was not statistically significant at $\alpha = 0.05$. Further details are available in Supplemental Table S4.

Table S4. Summary of comparative descriptive statistics of targeted outcomes

Variable	STEMCats				Control				Statistical test outcome‡		Effect size
	N	%	Mean	SD	N	%	Mean	SD	z score	t (df)	Hedges's *g*
Retention											
Freshman-year STEM retention	102	82.4			376	79.3			0.69 (p = 0.490)		
Sophomore-year STEM retention	102	73.5			376	64.6			1.70 (p = 0.091)		
Lower division STEM courses											
Course enrollment	103		6.44	2.48	376		5.72	2.48		2.61** (477) (p = 0.009)	0.29
Credit enrollment	103		16.96	7.00	376		14.90	6.77		2.72** (477) (p = 0.007)	0.30
Course pass-rate†	96		89.62	20.34	354		82.27	28.54		2.36* (448) (p = 0.018)	0.27
Earned STEM credits	103		15.46	7.60	376		12.97	7.64		2.93** (477) (p = 0.004)	0.33
STEM GPA† (0.00 – 4.00)	96		2.68	0.92	343		2.66	1.04		0.17 (437) (p = 0.865)	0.02
Upper division STEM courses											
Course enrollment	103		2.40	2.30	376		2.15	2.23		1.00 (477) (p = 0.317)	0.11
Credit enrollment	103		7.26	7.50	376		6.35	7.04		1.15 (477) (p = 0.252)	0.13
Course pass-rate†	62		95.32	14.05	213		92.60	22.33		0.91 (273) (p = 0.365)	0.13
Earned STEM credits	103		6.93	7.43	376		6.05	6.98		1.12 (477) (p = 0.264)	0.12
STEM GPA† (0.00 – 4.00)	62		2.89	0.79	209		2.90	0.88		0.08 (269) (p = 0.936)	-0.01

‡z-test for proportions, and independent samples t-test for means

†Percentage of passed courses per student, calculation is limited to the number of students who took the respective courses

*p < 0.05; **p < 0.01 (two-tailed)

Table S5. Summary of bivariate correlations between STEMCats participation and outcomes

Variable	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**	**11.**	**12.**	**13.**
1. STEMCats participation	1	0.032	0.077	0.118**	0.124**	0.111*	0.133**	0.008	0.045	0.052	0.055	0.051	-0.006
2. Freshman-year STEM retention		1	0.654**	0.357**	0.359**	0.307**	0.384**	0.301**	0.419**	0.390**	0.067	0.377**	0.008
3. Sophomore-year STEM retention			1	0.329**	0.338**	0.322**	0.388**	0.372**	0.523**	0.499**	0.176**	0.489**	0.123*
4. Lower division STEM course Enrollment				1	0.987**	0.511**	0.926**	0.367**	0.379**	0.331**	0.016	0.316**	-0.132*
5. Lower division STEM credit enrollment					1	0.483**	0.933**	0.367**	0.387**	0.339**	0.017	0.323**	-0.122*
6. Lower division STEM course pass-rate						1	0.722**	0.705**	0.478**	0.442**	0.200**	0.433**	0.231**
7. Lower division STEM credits earned							1	0.581**	0.504**	0.452**	0.089	0.437**	-0.014
8. Lower division STEM GPA								1	0.684**	0.644**	0.292**	0.644**	0.731**
9. Upper division STEM course Enrollment									1	0.985**	0.264**	0.970**	0.459**
10. Upper division STEM credit enrollment										1	0.230**	0.987**	0.431**
11. Upper division STEM course pass-rate											1	0.411**	0.510**
12. Upper division STEM credits earned												1	0.496**
13. Upper division STEM GPA													1

*$p < 0.05$; **$p < 0.01$ (two-tailed)

Table S6. The corresponding evaluation phase, activity and outcome from the Corwin model for selected survey items from STEMCats Survey 1 for assessing perceived gains from SRE toward enhancing STEM retention

Evaluation phase as per Corwin model	Outcome assessed [i.e. Likert-survey item from STEMCats Survey 1]	Corresponding activity/outcome from Corwin model‡
Early	'Improved your scientific thinking'	-A corresponding outcome is not depicted in the Corwin Model. By logical reasoning, this survey item is an outcome of a combination of depicted activities 'Read and evaluate current science literature', 'Select or design all or part of data collection methods', 'Collect novel data', 'Analyze results' in the Corwin Model -By logical reasoning, a 'short-term' outcome
	'Improved your science/STEM knowledge'	-Outcome: 'Increased content knowledge' -A 'short-term' outcome
	'Improved your experimentation skills'	-Outcome: 'Increased technical skills' -A 'short-term' outcome
Middle	'Improved your comfort level with other STEM students'	-Activity: 'Work collaboratively with peers' -Outcome: 'Increased collaboration skills' -A 'short-term' outcome
	'Improved your comfort-level with faculty'	-A corresponding outcome is not depicted in the Corwin Model. By logical reasoning, this survey item is an outcome that will lead to 'Sense of belonging to a larger community' -By logical reasoning, a 'short-term' outcome
	'Enhanced your sense that you are part of a group'	-Outcome: 'Sense of belonging to a larger community' -A 'short-term' outcome and a 'hub'
Late	'Enhanced your motivation/enthusiasm for STEM'	-Outcome: 'Increased motivation in science' -A 'medium-term' outcome
	'Enhanced your motivation towards accomplishing graduation from your STEM degree'	-Outcome: 'Persistence in science' -A 'long-term' outcome, a 'pinnacle' outcome

‡A schematic of the Corwin model is available in Figure 5 of Corwin et al., 2015

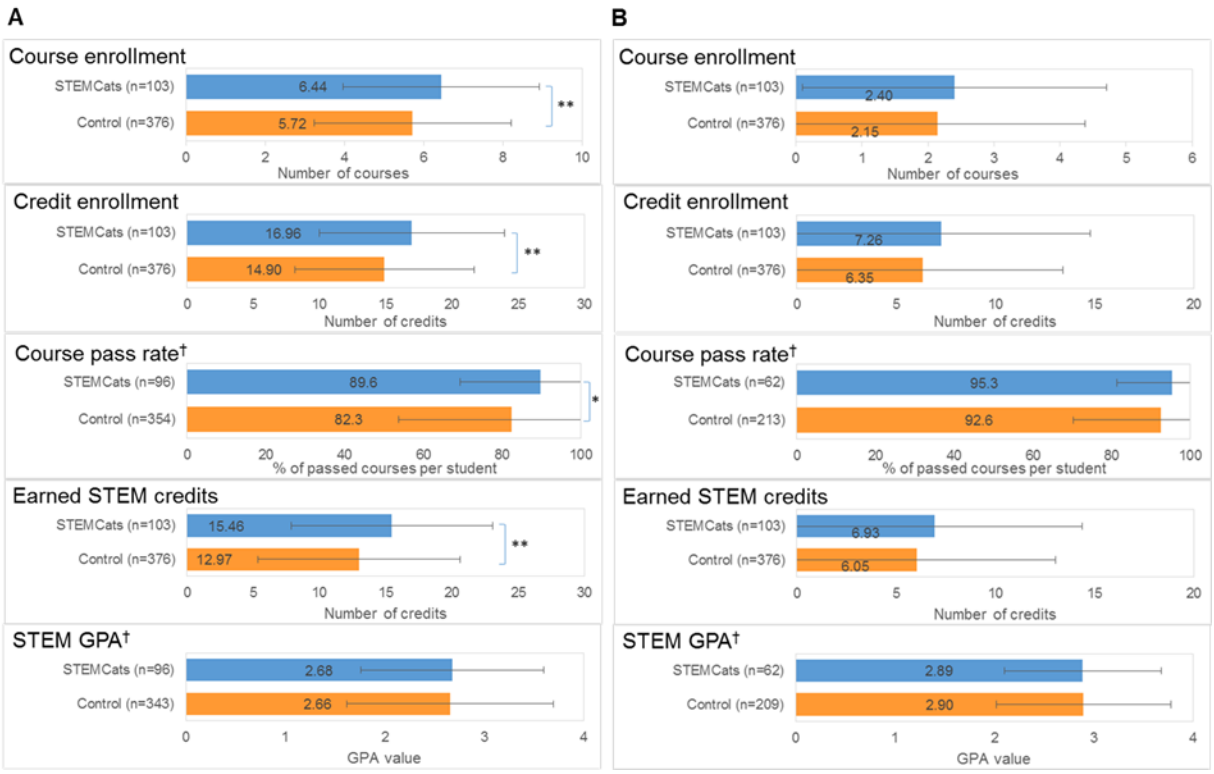

Figure S2. Descriptive data comparison for STEM academic performance outcomes between STEMCats and non-STEMCats control, as of end of the sophomore-year. Mean performance values are depicted for (A) lower-division STEM courses, and (B) upper-division STEM courses, with error bars denoting SD. Further details are available in Supplemental Table S4. *$p < 0.05$; **$p < 0.01$ (two-tailed independent samples t-test). †Calculation is limited to the number of students who took the respective courses.

Table S7. Multiple linear regression predicting course enrollment, credit enrollment and course pass-rate for lower-division STEM courses, as of the end of sophomore-year, for STEMCats and control groups from Biology and Chemistry majors

	Course Enrollment			Credit Enrollment			Pass-Rate		
	Standardized coefficient	Unstandardized coefficients		Standardized coefficient	Unstandardized coefficients		Standardized coefficient	Unstandardized coefficients	
	Beta	B	SE B	*Beta*	B	SE B	*Beta*	B	SE B
Constant		-3.010**	1.061		-9.537**	2.919		-1.931	11.590
STEMCat (1) vs. non-STEMCat (0)	0.193	1.135*** ($p < 0.001$)	0.252	0.198	3.222*** ($p < 0.001$)	0.692	0.146	9.306*** ($p < 0.001$)	2.633
High-School GPA (weighted out of 5)	0.240	1.193***	0.278	0.229	3.146***	0.765	0.131	7.306*	3.006
ACT Math	0.281	0.151***	0.032	0.300	0.447***	0.088	0.156	0.963**	0.337
Female (1) vs. Male (0)	-0.004	-0.019	0.223	-0.007	-0.104	0.613	-0.023	-1.218	2.314
STEM minority (1) vs. STEM non-minority (0)	-0.102	-0.669*	0.302	-0.107	-1.942*	0.830	-0.005	-0.339	3.234
Out of state (1) vs. in state (0)	-0.090	-0.490*	0.239	-0.076	-1.139	0.658	0.000	0.010	2.529
Pell grant recipient (1) vs. non-recipient (0)	-0.067	-0.356	0.247	-0.072	-1.055	0.679	-0.064	-3.739	2.596
First generation (1) vs. not first generation (0)	0.014	0.082	0.258	0.015	0.240	0.711	-0.028	-1.790	2.738
Academic major at the beginning of research experience: Chemistry (1) vs. Biology (0)	-0.014	-0.085	0.265	-0.001	-0.021	0.729	-0.081	-5.285	2.712
UK first semester GPA	0.299	0.789***	0.133	0.286	2.084***	0.367	0.440	13.184***	1.445
UK first semester earned credit hours	-0.452	-0.064***	0.008	-0.439	-0.171***	0.023	-0.042	-0.067	0.089
St. Error of Regression	2.078			5.716			21.214		
R^2	28.6%			29.2%			36.3%		
Adjusted R^2	26.7%			27.3%			34.5%		
F statistic	F = 14.834, df = (11, 407), $p < 0.001$			F = 15.268, df = (11, 407), $p < 0.001$			F = 19.948, df = (11, 385), $p < 0.001$		
Sample sizes n_1 = number of STEMCats, n_2 = number of non-STEMCats	$n_1 = 91$, $n_2 = 328$			$n_1 = 91$, $n_2 = 328$			$n_1 = 86$, $n_2 = 311$		
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$									

Table S8. Multiple linear regression predicting credits earned and GPA for lower-division STEM courses, as of the end of sophomore-year, for STEMCats and control groups from Biology and Chemistry majors

	Credits Earned			STEM GPA		
	Standardized coefficient	Unstandardized coefficients		Standardized coefficient	Unstandardized coefficients	
	Beta	B	SE B	*Beta*	B	SE B
Constant		-16.271***	3.113		-3.070***	0.326
STEMCat (1) vs. non-STEMCat (0)	0.206	3.769*** ($p < 0.001$)	0.738	0.051	0.132 ($p = 0.079$)	0.075
High-School GPA (weighted out of 5.000)	0.224	3.462***	0.815	0.197	0.446***	0.085
ACT Math	0.272	0.457***	0.094	0.310	0.078***	0.010
Female (1) vs. Male (0)	0.004	0.055	0.654	-0.005	-0.011	0.066
STEM minority (1) vs. STEM non-minority (0)	-0.078	-1.605	0.885	0.024	0.073	0.092
Out of state (1) vs. in state (0)	-0.062	-1.052	0.702	0.019	0.045	0.072
Pell grant recipient (1) vs. non-recipient (0)	-0.064	-1.066	0.724	-0.064	-0.155*	0.074
First generation (1) vs. not first generation (0)	-0.016	-0.287	0.758	-0.010	-0.025	0.078
Academic major at the beginning of research experience: Chemistry (1) vs. Biology (0)	-0.038	-0.719	0.777	-0.030	0.078	0.078
UK first semester GPA	0.406	3.342***	0.391	0.512	0.630***	0.041
UK first semester earned credit hours	-0.366	-0.161***	0.024	0.016	0.001	0.003
St. Error of Regression	6.095			0.607		
R^2	36.7%			69.3%		
Adjusted R^2	34.9%			68.5%		
F statistic	$F = 21.411$, $df = (11, 407)$, $p < 0.001$			$F = 79.726$, $df = (11, 388)$, $p < 0.001$		
Sample sizes n_1 = number of STEMCats, n_2 = number of non-STEMCats	$n_1 = 91$, $n_2 = 328$			$n_1 = 88$, $n_2 = 312$		
*$p < 0.05$; ***$p < 0.001$						

Table S9. Multiple linear regression predicting course enrollment, credit enrollment and course pass-rate for upper-division STEM courses, as of the end of sophomore-year, for STEMCats and control groups from Biology and Chemistry majors

	Course Enrollment			Credit Enrollment			Pass-Rate		
	Standardized coefficient	Unstandardized coefficients		Standardized coefficient	Unstandardized coefficients		Standardized coefficient	Unstandardized coefficients	
	Beta	B	SE B	*Beta*	B	SE B	*Beta*	B	SE B
Constant		-5.615***	0.773		-15.256***	2.508		42.819**	15.647
STEMCat (1) vs. non-STEMCat (0)	0.078	0.425* (p = 0.021)	0.183	0.080	1.402* (p = 0.019)	0.595	0.095	4.466 (p = 0.133)	2.961
High-School GPA (weighted out of 5)	0.126	0.582**	0.202	0.103	1.518*	0.657	0.101	4.687	3.497
ACT Math	0.282	0.141***	0.023	0.268	0.430***	0.076	0.036	0.204	0.428
Female (1) vs. Male (0)	-0.042	-0.196	0.162	-0.062	-0.916	0.527	0.059	2.417	2.612
STEM minority (1) vs. STEM non-minority (0)	-0.018	-0.109	0.220	-0.020	-0.387	0.713	-0.010	-0.668	4.353
Out of state (1) vs. in state (0)	-0.010	-0.049	0.174	-0.006	-0.096	0.565	0.061	2.750	2.932
Pell grant recipient (1) vs. non-recipient (0)	0.031	0.151	0.180	0.030	0.476	0.583	0.082	3.823	3.145
First generation (1) vs. not first generation (0)	-0.026	-0.140	0.188	-0.022	-0.372	0.611	-0.015	-0.805	3.388
Academic major at the beginning of research experience: Chemistry (1) vs. Biology (0)	-0.128	-0.731***	0.193	-0.172	-3.132***	0.626	-0.065	-3.102	3.039
UK first semester GPA	0.247	0.603***	0.097	0.217	1.702***	0.315	0.216	7.151**	2.348
UK first semester earned credit hours	0.276	0.036***	0.006	0.313	0.131***	0.020	0.027	0.030	0.086
St. Error of Regression	1.513			4.911			19.224		
R^2	56.0%			54.7%			10.8%		
Adjusted R^2	54.8%			53.4%			6.6%		
F statistic	F = 47.024, df = (11, 407), p < 0.001			F = 44.601, df = (11, 407), p < 0.001			F = 19.224, df = (11, 238), p < 0.001		
Sample sizes n_1 = number of STEMCats, n_2 = number of non-STEMCats	n_1 = 91 n_2 = 328			n_1 = 91, n_2 = 328			n_1 = 58, n_2 = 192		
*p < 0.05; **p < 0.01; ***p < 0.001									

Table S10. Multiple linear regression predicting credits earned and GPA for upper-division STEM courses, as of the end of sophomore-year, for STEMCats and control groups from Biology and Chemistry majors

	Credits Earned			GPA		
	Standardized coefficient	Unstandardized coefficients		Standardized coefficient	Unstandardized coefficients	
	Beta	B	SE B	*Beta*	B	SE B
Constant		-15.512***	2.476		-2.109***	0.560
STEMCat (1) vs. non-STEMCat (0)	0.080	1.391* (p = 0.018)	0.587	0.097	0.212 (p = 0.055)	0.110
High-School GPA (weighted out of 5.000)	0.106	1.549*	0.648	0.191	0.404**	0.128
ACT Math	0.259	0.411***	0.075	0.218	0.056***	0.016
Female (1) vs. Male (0)	-0.055	-0.809	0.520	-0.010	-0.019	0.097
STEM minority (1) vs. STEM non-minority (0)	-0.015	-0.286	0.704	-0.072	-0.219	0.162
Out of state (1) vs. in state (0)	0.001	0.021	0.558	0.053	0.111	0.109
Pell grant recipient (1) vs. non-recipient (0)	0.036	0.569	0.576	0.074	0.160	0.117
First generation (1) vs. not first generation (0)	-0.019	-0.329	0.603	-0.025	-0.060	0.126
Academic major at the beginning of research experience: Chemistry (1) vs. Biology (0)	-0.170	-3.075***	0.618	-0.128	-0.283*	0.112
UK first semester GPA	0.219	1.698***	0.311	0.367	0.555***	0.087
UK first semester earned credit hours	0.326	0.135***	0.019	0.050	0.003	0.003
St. Error of Regression	4.847			0.717		
R^2	55.0%			42.2%		
Adjusted R^2	53.8%			39.6%		
F statistic	F = 45.293, df = (11, 407), $p < 0.001$			F = 15.893, df = (11, 239), $p < 0.001$		
Sample sizes n_1 = number of STEMCats n_2 = number of non-STEMCats	n_1 = 91, n_2 = 328			n_1 = 58, n_2 = 193		
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$						