

# **Supplemental Material**

*CBE—Life Sciences Education*

Clemmons *et al.*

## Supplement Materials

### **Supplemental Material 1. BioSkills Guide Program-Level Learning Outcomes**

For brevity, we use shorthand names for the 20 BioSkills Guide program-level learning outcomes (Clemmons, Timbrook, Herron, & Crowe, 2020) throughout the paper. Full text of learning outcomes, which were also included in the survey, are included for reference.

### **Supplemental Material 2. Supplemental Figures**

### **Supplemental Material 3. Supplemental Tables**

### **Supplemental Material 4. Supplemental Methods**

### **Supplemental Material 5. BioSkills Curriculum Survey for instructors.**

Questionnaire used to gather data on instructor perceptions of teaching and assessment of core competencies for RQ1, RQ2, and RQ3. Survey logic presented competencies as blocks in a random order. All web probing questions are shown, but survey logic dictated that respondents were only shown three total probing questions.

The version of the questionnaire administered in Department E is shown. The questionnaire varied slightly across departments, depending on preference of pilot collaborator (welcome pages were customized, number of courses instructors were asked to report on varied from 2-7, course characteristics questions varied as described in methods).

### **Supplemental Material 6. BioSkills Curriculum Survey for students.**

Questionnaire used to gather data on student perceptions of teaching of core competencies for RQ3. Survey logic presented competencies in a random order. All web probing questions are shown, but survey logic dictated that respondents were only shown three total probing questions. The questionnaire did not vary across courses.

# Supplemental Material 1. BioSkills Guide Program-Level Learning Outcomes

For brevity, we use shorthand names for the 20 BioSkills Guide program-level learning outcomes (Clemmons, Timbrook, Herron, & Crowe, 2020) throughout the paper. Full text of learning outcomes, which were also included in the survey (see Supplemental Materials 2 and 3), are included for reference.

## PROCESS OF SCIENCE

- **Scientific Thinking:** Explain how science generates knowledge of the natural world.
- **Information Literacy:** Locate, interpret, and evaluate scientific information.
- **Question Formulation:** Pose testable questions and hypotheses to address gaps in knowledge.
- **Study Design:** Plan, evaluate, and implement scientific investigations.
- **Data Interpretation & Evaluation:** Interpret, evaluate, and draw conclusions from data in order to make evidence-based arguments about the natural world.
- **Doing Research:** Apply science process skills to address a research question in a course-based or independent research experience.

## QUANTITATIVE REASONING

- **Numeracy:** Use basic mathematics (e.g., algebra, probability, unit conversions) in biological contexts.
- **Quantitative & Computational Data Analysis:** Apply the tools of graphing, statistics, and data science to analyze biological data.

## MODELING

- **Purpose of Models:** Recognize the important roles that scientific models, of many different types (conceptual, mathematical, physical, etc.), play in predicting and communicating biological phenomena.
- **Model Application:** Make inferences and solve problems using models and simulations.
- **Modeling:** Build and evaluate models of biological systems.

## INTERDISCIPLINARY NATURE OF SCIENCE

- **Connecting Scientific Knowledge:** Integrate concepts across other STEM disciplines (e.g., chemistry, physics) and multiple fields of biology (e.g., cell biology, ecology).
- **Interdisciplinary Problem Solving:** Consider interdisciplinary solutions to real-world problems.

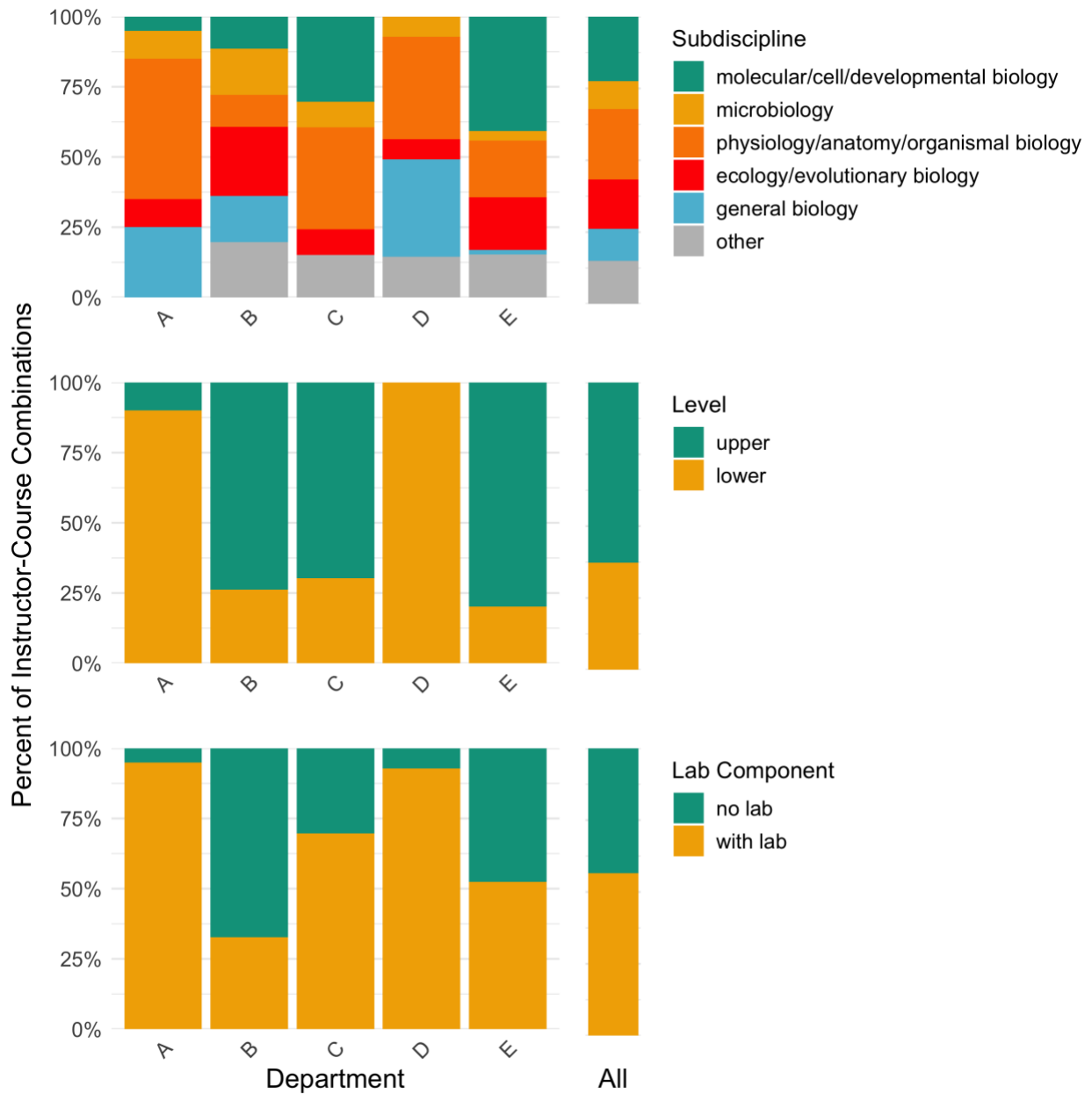
## **COMMUNICATION & COLLABORATION**

- **Communication:** Share ideas, data, and findings with others clearly and accurately.
- **Collaboration:** Work productively in teams with people who have diverse backgrounds, skill sets, and perspectives.
- **Collegial Review:** Provide and respond to constructive feedback in order to improve individual and teamwork.
- **Metacognition:** Reflect on your own learning, performance, and achievements.

## **SCIENCE & SOCIETY**

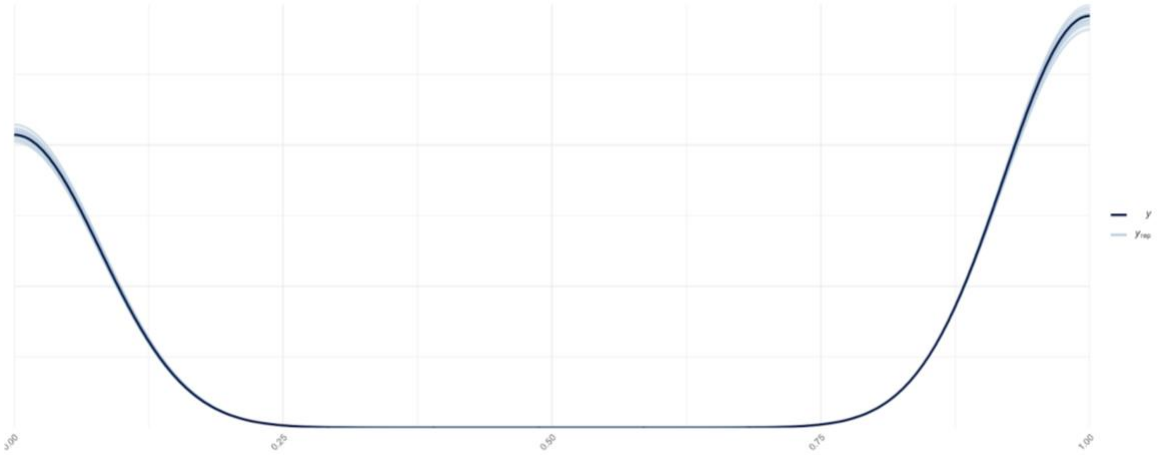
- **Ethics:** Demonstrate the ability to critically analyze ethical issues in the conduct of science.
- **Societal Influences:** Consider the potential impacts of outside influences (historical, cultural, political, technological) on how science is practiced.
- **Science's Impact on Society:** Apply scientific reasoning in daily life and recognize the impacts of science on a local and global scale.

## Supplemental Material 2. Supplemental Figures



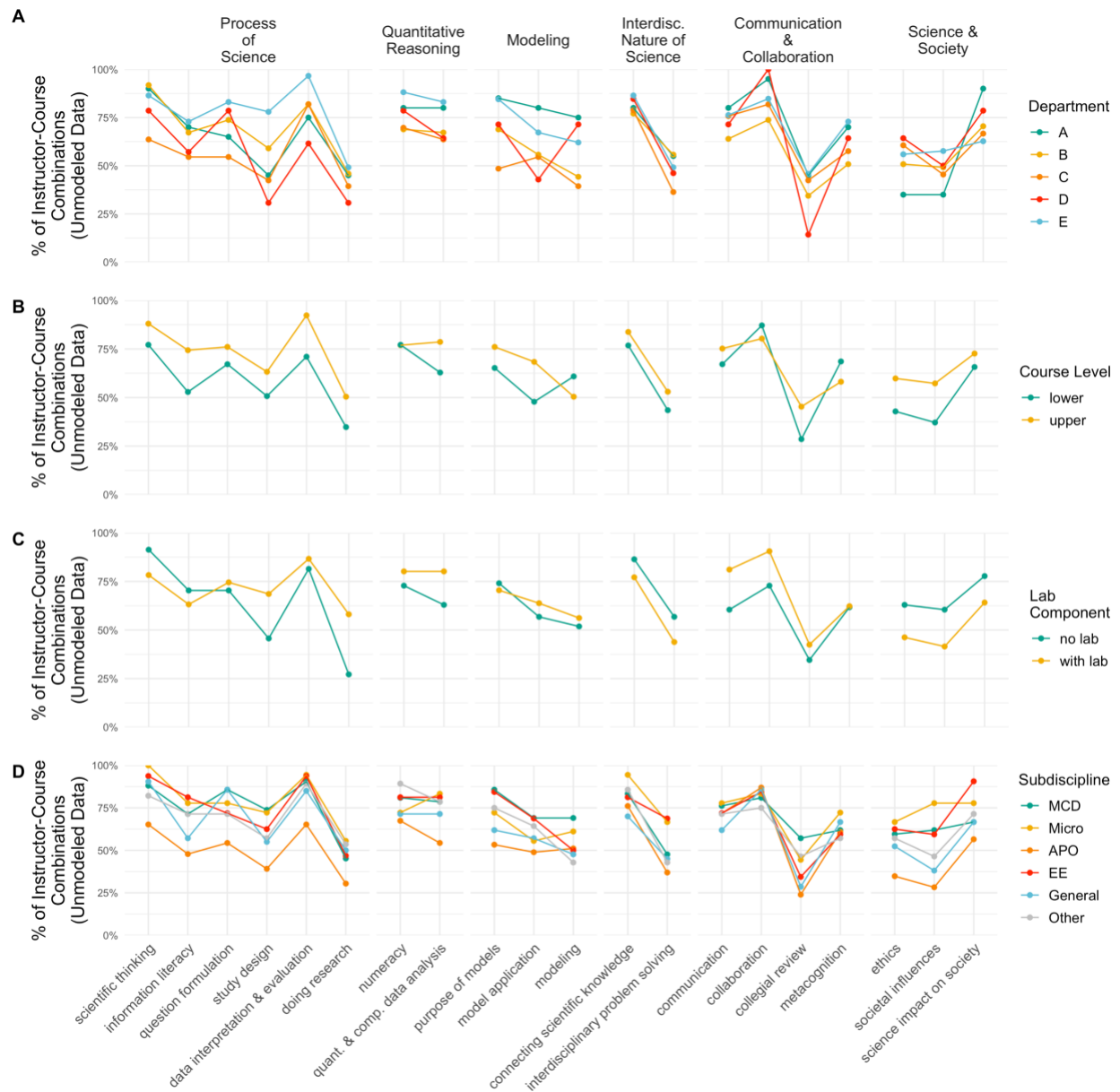
**Supplemental Figure 1. Distributions of course subdisciplines, level, and inclusion of lab component across instructor survey dataset, disaggregated by department and across all departments.**

n instructor-course combinations per department are 20, 61, 33, 14, 59 for Departments A, B, C, D, and E, respectively (overall n=187). Data in “All” columns is replicated from Figure 2 for comparison with individual department distributions.



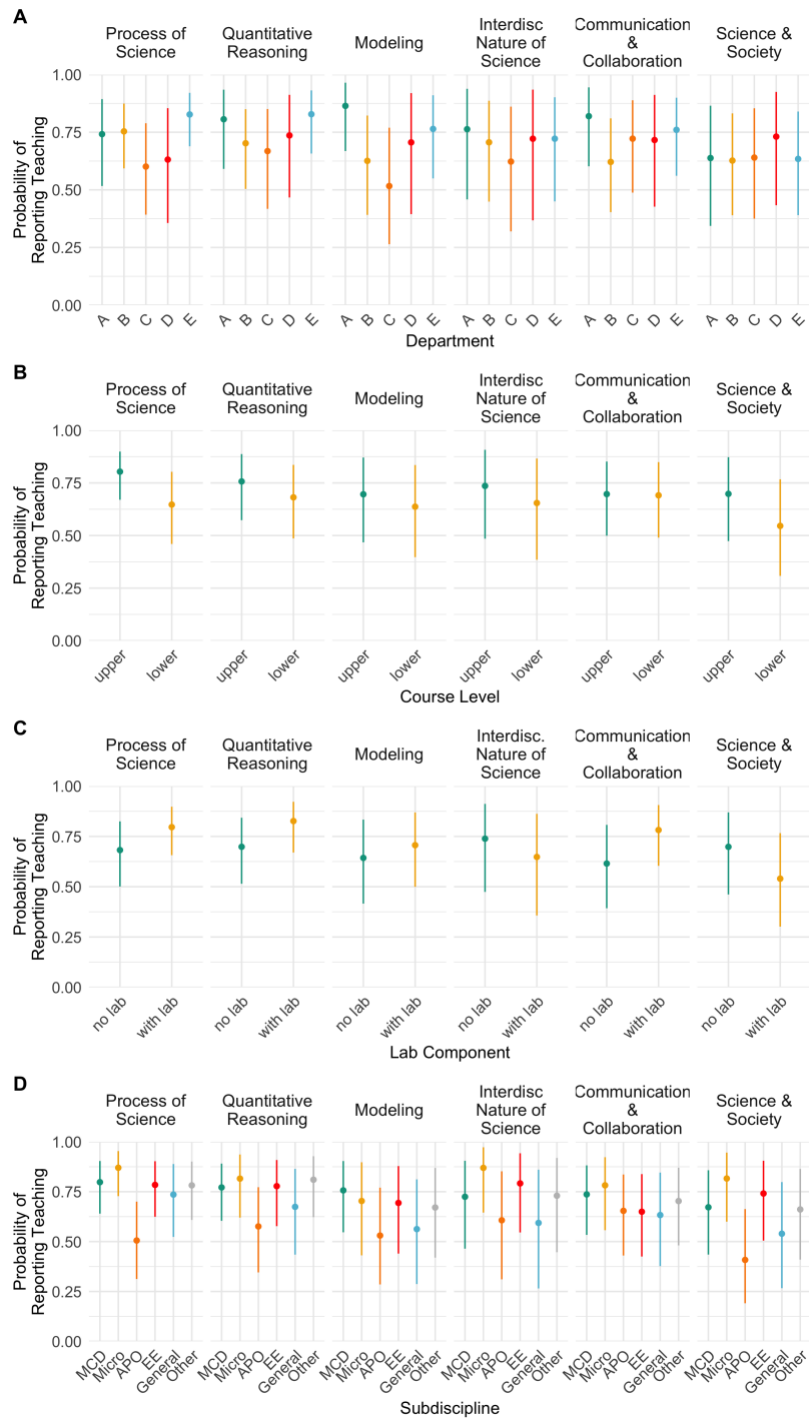
**Supplemental Figure 2. Posterior predictive check.**

Comparison of observed ( $y$ , dark blue) and simulated ( $y_{rep}$ , light blue) values. The distributions of  $y_{rep}$  and  $y$  are extremely similar, indicating that the final model fits the data well. Posterior predictive check for Model #7 is shown (see Table 1), however all other posterior predictive charts showed equal or better fit between simulated and observed values. Chart was generated using shinystan app (Muth, Oravecz, & Gabry, 2018).



**Supplemental Figure 3. Differences in reported teaching of BioSkills learning outcomes by department, course level, inclusion of a lab component, or subdiscipline.**

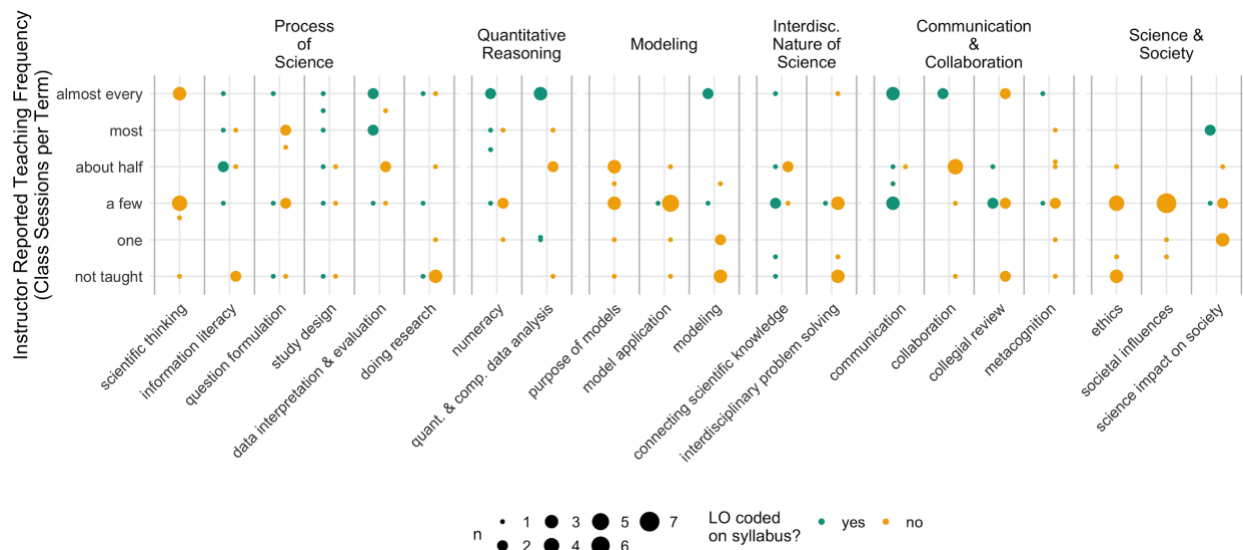
Unmodeled survey data of reported teaching disaggregated by course characteristics. Points show percent of instructor-course combinations in indicated subgroup where respondents reported teaching corresponding BioSkills learning outcome in “a few” or more class sessions. Connecting lines are included to ease tracking of individual data points. Subdiscipline of course could be Molecular/Cell/Developmental Biology (MCD), Microbiology, Anatomy/Physiology/Organismal Biology (APO), Ecology/Evolutionary Biology (EE), General Biology, or Other.



**Supplemental Figure 4. Likelihood of reporting teaching of particular competencies varies by course type.**

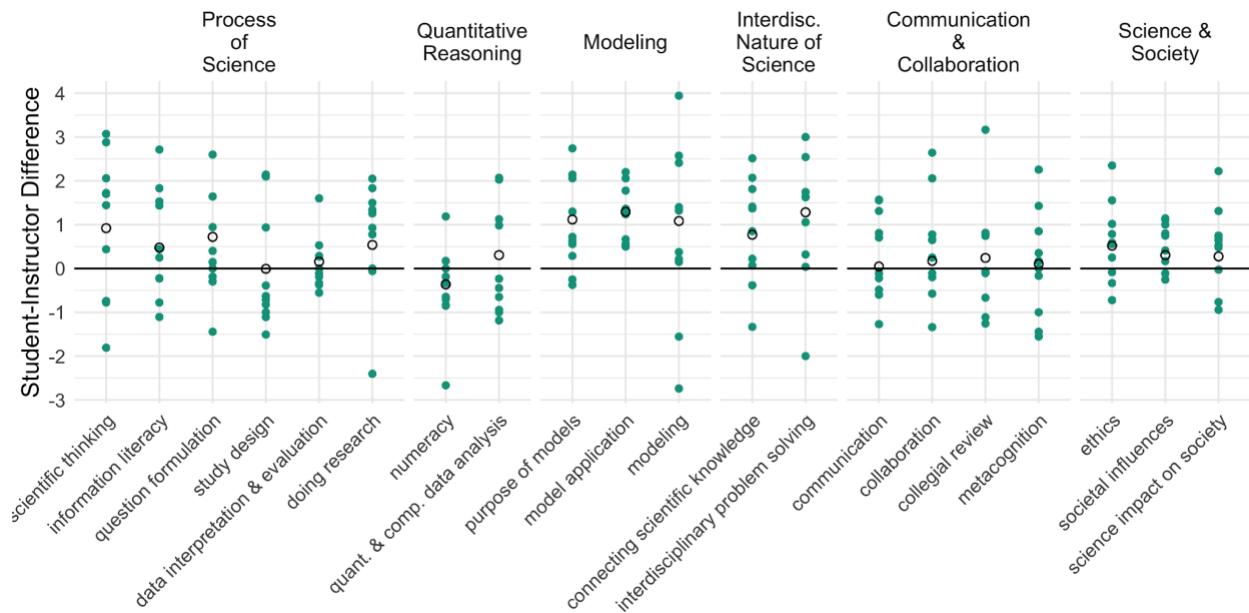
Model-based estimates of the probability of an instructor of the indicated course type reporting teaching of a learning outcome in the indicated competency. Points indicate means of the posterior distribution and vertical lines indicate Bayesian 95% credible intervals. Subdiscipline of course could be Molecular/Cell/Developmental Biology (MCD), Microbiology, Anatomy/Physiology/Organismal Biology (APO), Ecology/Evolutionary Biology (EE), General Biology, or Other.





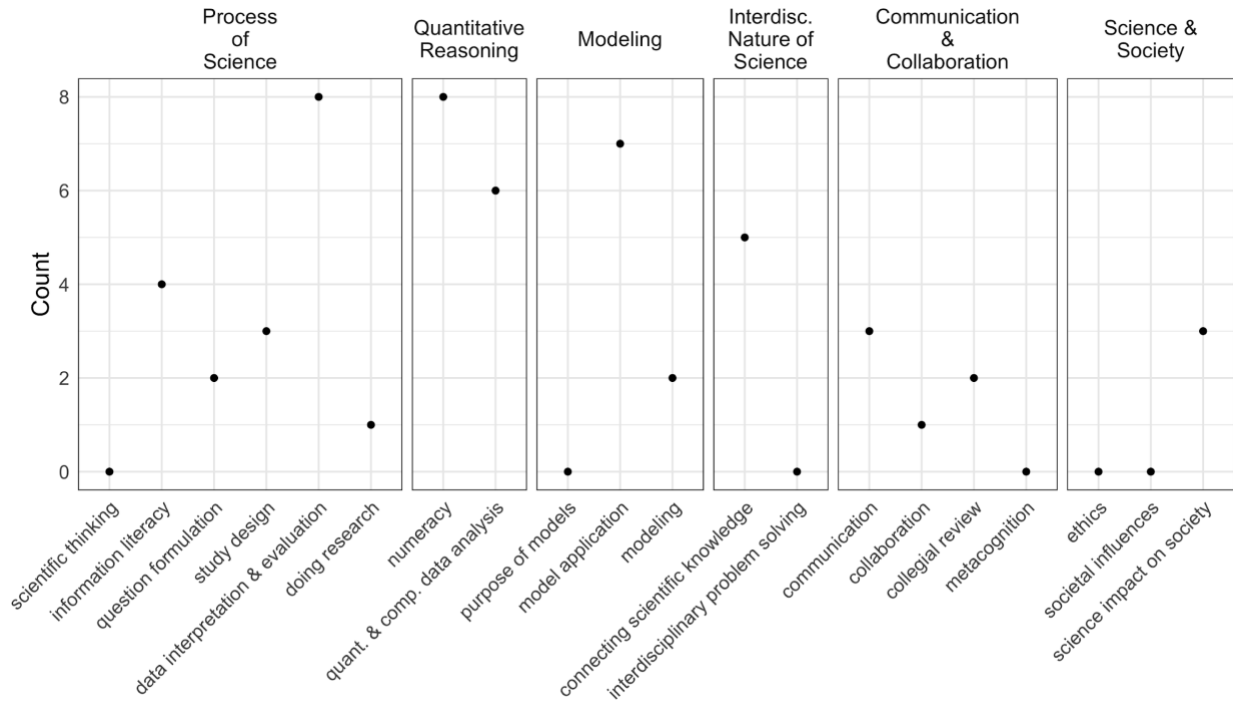
**Supplemental Figure 5. Learning outcomes represented on syllabi appear to be reported taught at higher frequencies.**

Comparison of instructor-reported teaching frequency (unmodeled data) for each BioSkills learning outcome with whether that learning outcome (LO) was coded on their syllabus. Point size is scaled to show the number of cases (out of 9 possible).



**Supplemental Figure 6. Students are more likely to report higher teaching frequencies relative to instructors.**

We calculated student-instructor difference for each course by subtracting the instructor-reported teaching frequency from the mean student-reported teaching frequency in their course, treating the six-point scale as numeric. Each blue point represents a different course, and open circles show average across all 10 RQ2/RQ3 courses. Points below zero indicate students on average reported less frequent teaching relative to their instructor. Points above zero indicate students on average reported more frequent teaching relative to their instructor.



**Supplemental Figure 7. Representation of core competency learning outcomes across coded exams.**

Points indicate the number of courses (out of nine) where that program-level BioSkills Guide learning outcome was coded on one or more exams.

## Supplemental Material 3. Supplemental Tables

### Supplemental Table 1. Coding of web probing question responses for evidence of validity of response processes.

<sup>a</sup> Response rates indicate the % of cases where respondents answered probing responses. 2.3% and 0.3% of probing questions were skipped by instructor and student survey respondents, respectively.

<sup>b</sup> See Methods and Supplemental Methods for details on coding scheme.

Survey	n responses coded (response rate % <sup>a</sup> )	Percent of responses with “valid response process” code <sup>b</sup>	Percent of responses with “survey error” code <sup>b</sup>
Instructor Survey	353 (97.7%)	96.2%	10.4%
Student Survey	262 (99.7%)	91.7%	15.9%

### Supplemental Table 2. Overview of curriculum mapping survey participants.

<sup>a</sup> Number of respondents after data cleaning. This number is an estimate. Instructors in departments C and D took the survey anonymously, so these counts do not account for individuals who may have taken the survey more than once from different devices. Counts for departments A, B, and E are based on respondent name, however a small number of respondents did not enter a name and therefore may be counted more than once if they had more than one survey session.

<sup>b</sup> Percent of possible instructors or courses from that department represented in dataset, based on estimate of number of instructors and number of regularly offered courses from collaborators in each department.

<sup>c</sup> Instructor-course combination is defined by a particular respondent reporting on a particular course.

<sup>d</sup> We were unable to get an estimate of the total number of courses regularly offered in Department B.

Department	n respondents <sup>a</sup> (response rate <sup>b</sup> )	n courses (response rate <sup>b</sup> )	n instructor-course combinations <sup>c</sup>	n student survey + class materials
A	11 (64.7% response)	11 (100% response)	20 (10.7% of total)	0
B	36 (51.4% response)	50 <sup>d</sup>	61 (32.6% of total)	0
C	21 (63.6% response)	26 (57.8% response)	33 (17.6% of total)	0
D	13 (50% response)	7 (87.5% response)	14 (7.5% of total)	0
E	27 (90% response)	33 (97.1% response)	59 (31.6% of total)	10
Total	108	127	187	10

**Supplemental Table 3. Instructor responses to the question “How was [learning outcome] assessed in this course?”**

<sup>a</sup> Assessment mode survey question responses were qualitatively coded as described in Methods.

<sup>b</sup> Percent of responses, out of 1,958 coded, across all instructor-course combinations and learning outcomes. Codes were not mutually exclusive and therefore do not sum to 100%.

<b>Code <sup>a</sup></b>	<b>Description</b>	<b>% of total <sup>b</sup></b>
Exams and Quizzes	Exams, quizzes, and other question-based summative assessments (e.g., “exam”, “quiz”, “post-lab assessment”)	54.3%
Writing, Presentations, and Projects	Summative assessments with a project- and/or communication-focus (e.g., “writing assignment”, “lab report”, “poster presentation”, “group project”)	37.6%
Practice Exercises	Formative assessment in or out of class (e.g., “homework”, “think-pair-share”, “class discussions”, “data analysis assignment”)	40.3%
Self and Peer Evaluation	Assignments where students were asked to reflect on their own or others’ performance or ideas (e.g., “peer review of poster presentations”, “exam wrapper”, “mid-quarter survey”)	5.7%
Lab Work	Process-oriented work that takes place in a lab setting (e.g., “lab assignments”, “dissections”, “lab progress”, “lab notebooks”, “lab meetings”)	14.4%

**Supplemental Table 4. Model fit statistics for RQ1 and RQ3.**

<sup>a</sup> Demonstration that inclusion of this parameter as a random effect is justified.

<sup>b</sup> For Models 1-3, the number of unique courses was 127. For Models 4-5, the number of unique courses was 125. For Models 6-7, the number of unique courses was 10. For Models 1-5, the number of unique respondents was 127. For Models 6-7, the number of unique respondents was 215. For all models, the number of unique learning outcomes was 20.

<sup>c</sup> Expected log predictive density (ELPD) is a metric of the predictive nature of the model, based on leaving one observation out at a time (leave-one-out; loo).

<sup>d</sup> p\_loo that is less than the total number of parameters indicates a well-specified model.

<sup>e</sup> Pareto k is an estimate useful in the importance sampling process, which is used to compute elpd\_loo. Specifically, Pareto k estimates how far an individual leave-one-out distribution is from the full distribution. If leaving one observation out changes the posterior distribution substantially, the importance sampling cannot generate reliable estimates. If  $k < 0.5$ , then elpd\_loo is estimated with high accuracy. When  $0.5 < k < 0.7$ , the accuracy of the importance sampling is lower but still ok; Pareto k values  $> 0.7$  indicate that the importance sampling does not generate a useful estimate when that observation is left out. All pareto k values were good ( $k < 0.5$ ) for seven of the ten models, indicating great fit of each of those models. The number of pareto k values above 0.5 (“ok”) or 0.7 (“bad”) are shown for the three other models.

<sup>f</sup> Conservatively, this model estimated 278 parameters ( $p = 6$  competencies + 125 courses + 127 respondents + 20 learning outcomes; (Gelman & Hill, 2007)), thus  $p_{loo} < p$ . While not optimal, the three large pareto k values are not catastrophic in this case. Importantly, the number of estimated parameters is relatively large compared to the number of observations ( $p > N/7$ :  $278 > 1860/7$ ; (Vehtari et al., 2020)). This simply indicates that the model has difficulty predicting the left out observation, which is likely due to relatively few observations per random effect (see Supplemental Methods – Pareto k), and does not indicate that the model is misspecified (Vehtari et al., 2020).

Model	n survey question responses	Estimate of the standard deviation of the random effect <sup>a</sup>			Leave-one-out estimate (SE)			
		Course <sup>b</sup>	Respondent <sup>b</sup>	Learning outcome <sup>b</sup>	Expected log predictive density: elpd (elpd_SE) <sup>c</sup>	Effective # of parameters: p_loo (p_loo_SE) <sup>d</sup>	# Pareto k values $> 0.5$ and $< 0.7$ <sup>e</sup>	# Pareto k values $> 0.7$ <sup>e</sup>
1	3732	0.77	0.94	0.92	-1965.6 (29)	148.8 (2.9)	0	0
2a	3732	0.79	0.94	0.89	-1955.0 (29.7)	166.0 (3.3)	0	0
2b	3732	0.73	0.95	0.89	-1963.2 (29.1)	153.0 (3.0)	0	0
2c	3732	0.81	0.94	0.89	-1938.1 (29.5)	153.8 (3.1)	1	0
2d	3732	0.66	0.96	0.90	-1963.3 (29.7)	166.8 (3.3)	0	0
3	2662	0.62	0.81	0.62	-1290.7 (27.4)	123.7 (3.3)	0	0
4	1860	2.27	1.77	0.96	-752.4 (24.4)	128.5 (5.9)	24	3 <sup>f</sup>
5	1860	1.91	1.34	0.86	-748.3 (25)	128.8 (5.3)	14	0
6	5240	0.2	0.38	0.38	-3409.5 (20.7)	113.4 (1)	0	0
7	5240	0.21	0.39	0.26	-3346.8 (23.5)	117.5 (1.1)	0	0

**Supplemental Table 5. Comparison of student and faculty perceptions of competency learning outcomes taught in 10 undergraduate biology courses in one department.**

<sup>a</sup> Number of learning outcomes, out of 20 BioSkills learning outcomes, where averaged student response and instructor response were within one response level on the 6-point teaching frequency response scale.

<sup>b</sup> After data cleaning, the number of students who completed the survey in each course and the response rate for each course as a percentage of total students enrolled

<sup>c</sup> Two courses (labeled E1 and E2) were sections of a course-based undergraduate research experience course with shared lecture, syllabus, and exams, but separate lab sections led by different instructors. Student responses in E1 and E2 were compared to their lab instructor's response.

Course	Student mean vs. instructor match $\leq 1$ <sup>a</sup>	n students (response rate) <sup>b</sup>
A	15	20 (87%)
B	14	27 (96.4%)
C	13	47 (94%)
D	13	17 (63%)
E1 <sup>c</sup>	13	14 (100%)
E2 <sup>c</sup>	12	16 (100%)
F	11	18 (81.8%)
G	10	59 (77.6%)
H	10	9 (75%)
I	6	35 (92.1%)
Total		262 (82.1%)

**Supplemental Table 6. Results of RQ1 modeling.**

<sup>a</sup> All models contained respondent, course, and learning outcome as random effects. Additional fixed effect predictor variables are indicated. Outcome variables (e.g., reported taught, reported assessed) for each model are indicated in header rows.

<sup>b</sup> Mean and upper and lower bounds of the 95% credible interval of the posterior distribution for each of the Bayesian multilevel logistic regression models used for RQ1. Boldface indicates estimates with 95% credible intervals that did not cross zero.

<sup>c</sup> The terms mcse, sd, and n\_eff are diagnostic statistics related to the MCMC chains, indicating model performance. mcse is the Monte Carlo standard error, representing the randomness associated with each MCMC estimation run. Low values of mcse relative to sd are desirable as large relative values will mask variation that is used to quantify the uncertainty in the estimate (i.e. the credible intervals). mcse is approximated by dividing the posterior standard deviation (sd) by the square root of the effective sample size (n\_eff), where n\_eff is the effective number of independent simulation draws within each MCMC chain. If the draws were independent, n\_eff would be 4,000 (4 chains x (2,000 iterations – 1,000 iterations of warm up)), but Markov chain simulations are almost always autocorrelated so n\_eff is usually smaller than 4,000.

Predictor Variable <sup>a</sup>	Level	Mean <sup>b</sup>	2.50% <sup>b</sup>	97.50% <sup>b</sup>	sd <sup>c</sup>	mcse <sup>c</sup>	n_eff <sup>c</sup>
<b>Model 1: Reported Taught</b>							
	(Intercept)	<b>1.38</b>	0.12	2.72	0.65	0.02	1574
Core Competency (ref = Quantitative Reasoning)	Process of Science	-0.24	-1.82	1.21	0.75	0.02	1568
	Modeling	-0.63	-2.26	0.96	0.83	0.02	1579
	Interdisciplinary Nature of Science	-0.41	-2.28	1.44	0.92	0.02	1719
	Communication & Collaboration	-0.51	-2.06	1.03	0.78	0.02	1740
	Science & Society	-0.88	-2.53	0.79	0.82	0.02	1737
<b>Model 2a: Reported Taught</b>							
	(Intercept)	<b>0.9</b>	0.02	1.73	0.44	0.01	2355
Core Competency (ref = Quantitative Reasoning)	Process of Science	0.26	-0.68	1.23	0.49	0.01	2622
	Modeling	-0.35	-1.46	0.77	0.58	0.01	2881
	Interdisciplinary Nature of Science	0.05	-1.15	1.27	0.62	0.01	3475
	Communication & Collaboration	-0.38	-1.45	0.69	0.55	0.01	2636
	Science & Society	-0.34	-1.41	0.78	0.56	0.01	2718
Pilot Department (ref = Department B)	Dept A	0.63	-0.29	1.55	0.46	0.01	3171
	Dept C	-0.15	-0.92	0.6	0.39	0.01	2910
	Dept D	0.22	-0.8	1.23	0.52	0.01	3657
	Dept E	<b>0.75</b>	0.02	1.47	0.36	0.01	2583
	Process of Science X Dept A	-0.67	-1.42	0.1	0.39	0.01	3718



Predictor Variable <sup>a</sup>	Level	Mean <sup>b</sup>	2.50% <sup>b</sup>	97.50% <sup>b</sup>	sd <sup>c</sup>	mcse <sup>c</sup>	n_eff <sup>c</sup>
Core Competency X Pilot Department (refs = Quantitative Reasoning, Department B)	Process of Science X Dept C	-0.58	-1.23	0.08	0.34	0.01	3340
	Process of Science X Dept D	-0.8	-1.65	0.01	0.42	0.01	4613
	Process of Science X Dept E	-0.29	-0.89	0.32	0.31	0.01	2869
	Modeling X Dept A	0.83	-0.03	1.67	0.44	0.01	4152
	Modeling X Dept C	-0.32	-1.09	0.41	0.38	0.01	4137
	Modeling X Dept D	0.21	-0.72	1.15	0.48	0.01	5347
	Modeling X Dept E	-0.05	-0.72	0.62	0.34	0.01	3392
	Interdisciplinary Nature of Science X Dept A	-0.27	-1.24	0.7	0.49	0.01	4783
	Interdisciplinary Nature of Science X Dept C	-0.24	-1.06	0.61	0.42	0.01	3752
	Interdisciplinary Nature of Science X Dept D	-0.08	-1.14	1.02	0.54	0.01	5456
	Interdisciplinary Nature of Science X Dept E	-0.66	-1.4	0.07	0.37	0.01	3204
	Communication & Collaboration X Dept A	0.47	-0.34	1.26	0.41	0.01	3880
	Communication & Collaboration X Dept C	0.65	-0.05	1.37	0.37	0.01	3473
	Communication & Collaboration X Dept D	0.28	-0.64	1.17	0.45	0.01	4891
	Communication & Collaboration X Dept E	-0.06	-0.71	0.58	0.32	0.01	3108
	Science & Society X Dept A	-0.57	-1.42	0.28	0.43	0.01	3910
	Science & Society X Dept C	0.22	-0.55	0.94	0.38	0.01	3655
	Science & Society X Dept D	0.34	-0.61	1.3	0.49	0.01	5644
Science & Society X Dept E	<b>-0.72</b>	-1.38	-0.08	0.34	0.01	3378	
<b>Model 2b: Reported Taught</b>							
	(Intercept)	0.79	-0.05	1.63	0.43	0.01	2182
Core Competency (ref = Quantitative Reasoning)	Process of Science	-0.16	-1.11	0.79	0.49	0.01	2168
	Modeling	-0.2	-1.32	0.9	0.57	0.01	2514

Predictor Variable <sup>a</sup>	Level	Mean <sup>b</sup>	2.50% <sup>b</sup>	97.50% <sup>b</sup>	sd <sup>c</sup>	mcse <sup>c</sup>	n_eff <sup>c</sup>
	Interdisciplinary Nature of Science	-0.1	-1.35	1.16	0.63	0.01	3196
	Communication & Collaboration	0.05	-0.98	1.11	0.52	0.01	2185
	Science & Society	-0.6	-1.7	0.51	0.57	0.01	2300
Course Level (ref = Lower Level)	Upper Level	0.39	-0.18	0.96	0.29	0.01	2038
Core Competency X Course Level (refs = Quantitative Reasoning, Lower Level)	Process of Science X Upper Level	0.43	-0.11	0.96	0.27	0.01	2474
	Modeling X Upper Level	-0.12	-0.73	0.47	0.3	0.01	2786
	Interdisciplinary Nature of Science X Upper Level	0.01	-0.65	0.66	0.33	0.01	3431
	Communication & Collaboration X Upper Level	-0.37	-0.93	0.19	0.28	0.01	2446
	Science & Society X Upper Level	0.3	-0.3	0.88	0.3	0.01	2907
<b>Model 2c: Reported Taught</b>							
	(Intercept)	<b>0.87</b>	0.06	1.68	0.42	0.01	1831
Core Competency (ref = Quantitative Reasoning)	Process of Science	-0.08	-1.03	0.91	0.49	0.01	2189
	Modeling	-0.25	-1.33	0.86	0.57	0.01	2420
	Interdisciplinary Nature of Science	0.25	-0.97	1.47	0.63	0.01	3238
	Communication & Collaboration	-0.38	-1.43	0.69	0.54	0.01	1823
	Science & Society	0.02	-1.05	1.09	0.55	0.01	2447
Whether Instructor-course combination Includes Reporting on Lab (ref = No Lab Component)	With Lab	<b>0.75</b>	0.22	1.3	0.28	0.01	2224
Core Competency X Whether Instructor-course combination Includes Reporting on Lab (refs = Quantitative Reasoning, No Lab Component)	Process of Science X With Lab	-0.14	-0.66	0.39	0.27	0.01	2732
	Modeling X With Lab	-0.45	-1.02	0.12	0.29	0.01	3023
	Interdisciplinary Nature of Science X With Lab	<b>-1.21</b>	-1.85	-0.57	0.33	0.01	3580
	Communication & Collaboration X With Lab	0.09	-0.45	0.66	0.28	0.01	2707
	Science & Society X With Lab	<b>-1.47</b>	-2.03	-0.89	0.29	0.01	2852
<b>Model 2d: Reported Taught</b>							
	(Intercept)	<b>1.27</b>	0.42	2.1	0.43	0.01	2162
	Quantitative Reasoning	0.16	-0.82	1.13	0.5	0.01	2113

Predictor Variable <sup>a</sup>	Level	Mean <sup>b</sup>	2.50% <sup>b</sup>	97.50% <sup>b</sup>	sd <sup>c</sup>	mcse <sup>c</sup>	n_eff <sup>c</sup>
Core Competency (ref = Quantitative Reasoning)	Modeling	-0.06	-1.18	1.09	0.57	0.01	2565
	Interdisciplinary Nature of Science	-0.22	-1.44	1.03	0.62	0.01	3450
	Communication & Collaboration	-0.19	-1.22	0.88	0.54	0.01	2532
	Science & Society	-0.5	-1.62	0.64	0.57	0.01	2925
Course Subdiscipline (ref = Molecular/Cell/ Developmental Biology)	Microbiology	0.31	-0.53	1.18	0.44	0.01	3272
	Physiology/Anatomy/Organismal biology	<b>-0.94</b>	-1.64	-0.28	0.35	0.01	2554
	Ecology/Evolutionary Biology	0.06	-0.69	0.8	0.38	0.01	2631
	General Biology	-0.49	-1.31	0.32	0.42	0.01	2381
	Other	0.27	-0.48	1.03	0.38	0.01	2542
Core Competency X Course Subdiscipline (refs = Quantitative Reasoning, Molecular/Cell/ Developmental Biology)	Quantitative Reasoning X Microbiology	0.26	-0.57	1.09	0.42	0.01	4295
	Modeling X Microbiology	-0.57	-1.47	0.35	0.46	0.01	4567
	Interdisciplinary Nature of Science X Microbiology	0.74	-0.28	1.8	0.53	0.01	5189
	Communication & Collaboration X Microbiology	-0.03	-0.9	0.82	0.45	0.01	4660
	Science & Society X Microbiology	0.53	-0.4	1.44	0.47	0.01	4970
	Quantitative Reasoning X Physiology/Anatomy/Organismal Biology	-0.46	-1.06	0.17	0.32	0.01	3225
	Modeling X Physiology/Anatomy/Organismal Biology	-0.13	-0.78	0.55	0.34	0.01	3583
	Interdisciplinary Nature of Science X Physiology/Anatomy/Organismal Biology	0.37	-0.37	1.13	0.38	0.01	3898
	Communication & Collaboration X Physiology/Anatomy/Organismal Biology	0.54	-0.11	1.19	0.33	0.01	3212
	Science & Society X Physiology/Anatomy/Organismal Biology	-0.22	-0.89	0.44	0.34	0.01	3189
	Quantitative Reasoning X Ecology/Evolutionary Biology	-0.14	-0.86	0.57	0.36	0.01	3267

Predictor Variable <sup>a</sup>	Level	Mean <sup>b</sup>	2.50% <sup>b</sup>	97.50% <sup>b</sup>	sd <sup>c</sup>	mcse <sup>c</sup>	n_eff <sup>c</sup>
	Modeling X Ecology/Evolutionary Biology	-0.38	-1.15	0.39	0.4	0.01	3665
	Interdisciplinary Nature of Science X Ecology/Evolutionary Biology	0.36	-0.5	1.24	0.45	0.01	4071
	Communication & Collaboration X Ecology/Evolutionary Biology	-0.48	-1.24	0.26	0.38	0.01	3363
	Science & Society X Ecology/Evolutionary Biology	0.3	-0.47	1.06	0.39	0.01	3341
	Quantitative Reasoning X General Biology	0.15	-0.61	0.9	0.39	0.01	3163
	Modeling X General Biology	-0.44	-1.32	0.37	0.43	0.01	4043
	Interdisciplinary Nature of Science X General Biology	-0.13	-1.05	0.81	0.47	0.01	5243
	Communication & Collaboration X General Biology	0	-0.79	0.77	0.4	0.01	3648
	Science & Society X General Biology	-0.1	-0.95	0.71	0.43	0.01	4225
	Quantitative Reasoning X Other	-0.36	-1.1	0.39	0.37	0.01	3218
	Modeling X Other	-0.7	-1.5	0.08	0.41	0.01	3740
	Interdisciplinary Nature of Science X Other	-0.22	-1.11	0.64	0.45	0.01	3837
	Communication & Collaboration X Other	-0.43	-1.19	0.32	0.39	0.01	3248
	Science & Society X Other	-0.31	-1.11	0.49	0.41	0.01	3482
<b>Model 3: Reported Assessed</b>							
	(Intercept)	<b>2.2</b>	1.29	3.11	0.46	0.01	1722
Core Competency (ref = Quantitative Reasoning)	Process of Science	-0.13	-1.21	0.89	0.52	0.01	1784
	Modeling	-0.93	-2.1	0.23	0.59	0.01	2016
	Interdisciplinary Nature of Science	-1.15	-2.47	0.1	0.65	0.01	2279
	Communication & Collaboration	<b>-1.7</b>	-2.83	-0.6	0.56	0.01	1756
	Science & Society	<b>-2.97</b>	-4.21	-1.82	0.6	0.01	1802
<b>Model 4: Reported Assessed with Writing/Presentation/Project</b>							
	(Intercept)	<b>-1.58</b>	-3.06	-0.04	0.76	0.02	1582
Core Competency (ref = Quantitative Reasoning)	Process of Science	0.76	-0.87	2.32	0.81	0.02	1386
	Modeling	-1.06	-2.89	0.71	0.91	0.02	1622
	Interdisciplinary Nature of Science	-0.35	-2.31	1.6	0.98	0.02	1861

Predictor Variable <sup>a</sup>	Level	Mean <sub>b</sub>	2.50% <sub>b</sub>	97.50% <sub>b</sub>	sd <sup>c</sup>	mcse <sub>c</sub>	n_eff <sup>c</sup>
	Communication & Collaboration	-0.37	-2.11	1.27	0.86	0.02	1595
	Science & Society	-0.25	-2.08	1.47	0.92	0.02	1819
<b>Model 5: Reported Assessed with Quiz/Exam</b>							
	(Intercept)	<b>1.43</b>	0.07	2.81	0.69	0.01	2194
Core Competency (ref = Quantitative Reasoning)	Process of Science	<b>-1.47</b>	-2.94	-0.03	0.73	0.02	2156
	Modeling	0.17	-1.4	1.84	0.82	0.02	2654
	Interdisciplinary Nature of Science	0	-1.77	1.83	0.92	0.02	2850
	Communication & Collaboration	<b>-4.29</b>	-5.97	-2.69	0.82	0.02	2378
	Science & Society	-1.06	-2.68	0.59	0.85	0.02	2650

**Supplemental Table 7. Pairwise comparisons of likelihood of reporting teaching in courses in different departments.**

<sup>a</sup> Text indicates direction of difference and OR indicates odds ratios (e.g., A > C OR: 2.6 indicates that courses in Department A were 2.6 times more likely to report teaching of the indicated competency than courses in Department C).

<sup>b</sup> For models 2a-2d, we made pairwise comparisons of each level of the interaction by systematically releveling the reference of the models in order to get estimates of the main effects of each level of core competency and course characteristic. Therefore, there was often more than one model that could be used to interpret whether such a pair-wise difference existed. In a small number of cases, which are marked with “note”, the credible interval crossed zero (and therefore the levels were interpreted as equivalent) in one model but not the other. This happened in cases where the difference was smaller, and so we are reporting the more conservative interpretation (i.e. that the levels are equivalent).

Reference Level	Comparison Level	Process of Science	Quantitative Reasoning	Modeling	Interdisciplinary Nature of Science	Communication & Collaboration	Science & Society
Dept A	Dept B	-	-	note <sup>b</sup>	-	note <sup>b</sup>	-
	Dept C	-	-	A > C OR: 2.6 <sup>a</sup>	-	-	-
	Dept D	-	-	-	-	-	-
	Dept E	-	-	-	-	-	-
Dept B	Dept C	-	-	-	-	-	-
	Dept D	-	-	-	-	-	-
	Dept E	-	E > B OR: 2.1 <sup>a</sup>	note <sup>b</sup>	-	note <sup>b</sup>	-
Dept C	Dept D	-	-	-	-	-	-
	Dept E	E > C OR: 2.5 <sup>a</sup>	E > C OR: 2 <sup>a</sup>	note <sup>b</sup>	-	-	-
Dept D	Dept E	-	-	-	-	-	-

**Supplemental Table 8. Pairwise comparisons of likelihood of student-instructor agreement in courses with different subdisciplinary foci.**

<sup>a</sup> Text indicates direction of difference and OR indicates odds ratios (e.g., MCD > APO OR: 2.7 indicates that courses with a Molecular, Cell, Developmental Biology focus were 2.7 times more likely to report teaching of the indicated competency than courses with an Anatomy, Physiology, Organismal Biology focus).

<sup>b</sup> For models 2a-2d, we made pairwise comparisons of each level of the interaction by systematically releveling the reference of the models in order to get estimates of the main effects of each level of core competency and course characteristic. Therefore, there was often more than one model that could be used to interpret whether such a pair-wise difference existed. In a small number of cases, which are marked with “note”, the credible interval crossed zero (and therefore the levels were interpreted as equivalent) in one model but not the other. This happened in cases where the difference was smaller, and so we are reporting the more conservative interpretation (i.e. that the levels are equivalent).

Reference Level	Comparison Level	Process of Science	Quantitative Reasoning	Modeling	Inter-disciplinary Nature of Science	Communication & Collaboration	Science & Society
Molecular, Cell, & Developmental Biology (MCD)	Microbiology	-	-	-	-	-	-
	APO	MCD > APO OR: 3.6 <sup>a</sup>	MCD > APO OR: 2.6 <sup>a</sup>	MCD > APO OR: 2.5 <sup>a</sup>	note <sup>b</sup>	-	MCD > APO OR: 3 <sup>a</sup>
	EE	-	-	-	-	-	-
	General Biology	-	-	-	-	-	-
	Other	-	-	-	-	-	-
Microbiology	APO	Micro > APO OR: 4.3 <sup>a</sup>	Micro > APO OR: 2.6 <sup>a</sup>	Micro > APO OR: 2.6 <sup>a</sup>	Micro > APO OR: 2.6 <sup>a</sup>	note <sup>b</sup>	Micro > APO OR: 3.8 <sup>a</sup>
	EE	-	-	-	-	-	-
	General Biology	note <sup>b</sup>	-	-	Micro > Gen OR: 2.4 <sup>a</sup>	-	Micro > Gen OR: 2.3 <sup>a</sup>
	Other	-	-	-	-	-	-
Anatomy, Physiology, & Organismal Biology (APO)	EE	EE > APO OR: 2.4 <sup>a</sup>	EE > APO OR: 2.1 <sup>a</sup>	EE > APO OR: 1.9 <sup>a</sup>	EE > APO OR: 2.3 <sup>a</sup>	-	EE > APO OR: 2.7 <sup>a</sup>
	General Biology	note <sup>b</sup>	-	-	-	-	-
	Other	Other > APO OR: 2.3 <sup>a</sup>	Other > APO OR: 2.6 <sup>a</sup>	-	-	-	Other > APO OR: 2 <sup>a</sup>
Ecology & Evolutionary Biology (EE)	General Biology	-	-	-	-	-	-
	Other	-	-	-	-	-	-
General Biology	Other	-	-	-	-	-	-

### Supplemental Table 9. Results of RQ3 modeling.

<sup>a</sup> Both models contained respondent, learning outcome, and course as random effects and student-instructor agreement as the outcome variable. Additional fixed effect predictor variables are indicated.

<sup>b</sup> Mean and upper and lower bounds of 95% credible intervals of the posterior distribution for each of the Bayesian multilevel logistic regression models. Boldface indicates estimates with 95% credible intervals that did not cross zero.

<sup>c</sup> The terms mcse, sd, and n\_eff are diagnostic statistics related to the MCMC chains, indicating model performance. mcse is the Monte Carlo standard error, representing the randomness associated with each MCMC estimation run. Low values of mcse relative to sd are desirable as large relative values will mask variation that is used to quantify the uncertainty in the estimate (i.e. the credible intervals). mcse is approximated by dividing the posterior standard deviation (sd) by the square root of the effective sample size (n\_eff), where n\_eff is the effective number of independent simulation draws within each MCMC chain. If the draws were independent, n\_eff would be 4,000 (4 chains x (2,000 iterations – 1,000 iterations of warm up)), but Markov chain simulations are almost always autocorrelated so n\_eff is usually smaller than 4,000.

Predictor variable <sup>a</sup>	Level	Mean <sup>b</sup>	2.50% <sup>b</sup>	97.50% <sup>b</sup>	sd <sup>c</sup>	mcse <sup>c</sup>	n_eff <sup>c</sup>
<b>Model 6: Student-Instructor Agreement</b>							
	(Intercept)	<b>0.88</b>	0.29	1.49	0.3	0.01	1305
Core Competency (ref = Quantitative Reasoning)	Process of Science	-0.61	-1.24	0.04	0.33	0.01	1261
	Modeling	<b>-1.07</b>	-1.79	-0.36	0.37	0.01	1489
	Interdisciplinary Nature of Science	<b>-0.96</b>	-1.78	-0.16	0.41	0.01	1464
	Communication & Collaboration	-0.28	-1.02	0.41	0.36	0.01	1397
	Science & Society	-0.12	-0.84	0.6	0.37	0.01	1605
<b>Model 7: Student-Instructor Agreement</b>							
	(Intercept)	0.09	-0.36	0.55	0.23	0.01	1341
Core Competency (ref = Quantitative Reasoning)	Process of Science	-0.28	-0.76	0.2	0.24	0.01	1239
	Modeling	<b>-0.7</b>	-1.25	-0.19	0.26	0.01	1505
	Interdisciplinary Nature of Science	-0.45	-1.03	0.11	0.29	0.01	1814
	Communication & Collaboration	0.21	-0.29	0.72	0.25	0.01	1378
	Science & Society	0.44	-0.11	0.99	0.27	0.01	1294
Whether Learning Outcome Was Represented on Exam(s) (ref = Not on Exam(s))	On Exam(s)	<b>0.63</b>	0.42	0.84	0.1	0	4187



Predictor variable <sup>a</sup>	Level	Mean <sup>b</sup>	2.50% <sup>b</sup>	97.50% <sup>b</sup>	sd <sup>c</sup>	mcse <sup>c</sup>	n_eff <sup>c</sup>
Whether Learning Outcome Was Reported Assessed (ref = Not Assessed)	Reported Assessed	<b>0.55</b>	0.4	0.7	0.08	0	5279
Whether Learning Outcome Was Represented on Syllabus (ref = Not on Syllabus)	On Syllabus	-0.16	-0.33	0.02	0.09	0	5498

## Supplemental Material 4. Supplemental Methods

### Survey Development

#### Initial Drafting

The first version of the BioSkills Curriculum Survey was developed as part of a multi-year curriculum review effort by a biology department at an R1 research university in the Northwestern United States. The goal was to gather department-wide data on the teaching of Vision and Change core competencies in order to identify gaps and redundancies in the curriculum. Thus, the survey was designed to measure current curricular alignment with program-level outcomes in the BioSkills Guide. The first survey draft was informed by a review of practitioner's resources for curriculum mapping (e.g., Allen, 2004; Hale, 2008; Partnership for Undergraduate Life Sciences Education, 2018), best practices in survey design (Dillman, Smyth, & Christian, 2014), and year-long conversations on the undergraduate curriculum committee in which two of the authors were involved (AWC, AJC).

This first survey draft asked instructors to report on the “extent of teaching” for each of the 20 BioSkills program-level learning outcomes. The question “To what extent is [learning outcome] taught in your course?” included the response options: “not covered”, “students are exposed to this”, “students practice this”, “students are graded on this”, and “this is a primary focus of the course”. We tested this draft through think-aloud interviews (Willis, 1999) with three biology faculty, an initial pilot survey in which approximately 50 faculty in one biology department participated, and a round table discussion at a national biology education conference.

The round table aimed to test whether the survey elicited consistent and expected interpretations by biology instructors outside of the institution where it was developed. Participants were undergraduate biology educators from a variety of institutions and thus were representative of our intended users. We asked participants to individually write their answer to the first draft question stem: “To what extent was [this learning outcome] taught in the course you most recently taught?” for two different competency learning outcomes. We purposefully omitted response options to see how respondents interpreted “extent of teaching”. Responses revealed at least 6 different types of responses (e.g., mastery, complexity, frequency, vague quantifiers) (see also Marbach-Ad et al., 2010). We concluded that “extent of teaching”, despite being commonly used in other curriculum mapping approaches (e.g., those that employ introductory, developing, mastery categories), was too vague a construct for use in a survey with fixed response options. This finding is corroborated by research evaluating methods for measuring alignment with curricular standards in K-12 education and methods for measuring the impact of professional development. There, researchers found that surveys are not valid or reliable methods for reporting on “depth” or other evaluative measures of teaching (Burstein et al., 1995; Desimone, 2009; Porter, 2002). However, surveys were found to be valid ways of measuring descriptions of the content of lessons and frequency of behaviors. Thus, we revised the survey question to focus on the frequency of teaching, operationalized as number of class sessions.

The curriculum survey was significantly revised based on this initial round of feedback. Most notably, we split the “extent of teaching” question into two components: teaching and assessment. To ask about teaching of core competencies, we revised the survey to ask about frequency of teaching, adapting a frequency response scale used in another survey instrument for college instructors and students (Marbach-Ad, Ziemer, Orgler, & Thompson, 2014). To ask about assessment of core competencies, we added questions about whether and how the learning outcomes were assessed. We added this based on the fact that curriculum mapping is often a precursor to programmatic student assessment, in order to identify courses where desired assessment data can be collected. We wished to enable departments using the BioSkills Curriculum Survey to apply data about how core competencies are already being assessed to develop programmatic assessment plans. Furthermore, by reporting on assessment, we learn more about the instructor’s relative emphasis of that learning outcome in their broader course, thus approximating some of the information desired with the “extent of teaching” question in the first draft.

We tested the revised survey through additional think-aloud interviews with seven biology instructors from five different institutions and expert review by one survey methodologist and four discipline-based education researchers. Through this testing we introduced small revisions to the response scale and instructional language.

### **Think-Aloud Interviews**

We tested iterative revisions of the instructor BioSkills Curriculum Survey for evidence of eliciting valid response processes through one-on-one think-aloud interviews (Willis, 1999). Ten total think-aloud interviews were conducted over the course of five revisions. We asked instructors to think aloud as they responded to the survey for a subset of learning outcomes (survey length was reduced for time). We purposefully included learning outcomes spanning a range of competencies (e.g., Numeracy and Collaboration) in this subset to elicit a range of different possible responses. All interviews were recorded and listened to post-interview to identify themes. Think-aloud interviews informed a number of revisions including adjustments to the response scale, examples, question stems, and other instructional language.

### **Web Probing Questions**

We included web probing questions (Behr, Meitinger, Braun, & Kaczmirek, 2017) when administering both the five-department instructor survey and the ten-course student survey to evaluate whether the survey elicited valid response processes when reporting on teaching frequency. In short, we used thematic analysis to see if open-ended responses to web-probing questions were in alignment with corresponding closed-ended responses.

For three of the 20 program-level learning outcomes, respondents were asked “How did you decide to select [response option inserted] for [learning outcome]?”, with the full text of the original question repeated below (i.e. “How frequently was [learning outcome] taught in this course?”, followed by the learning outcome text). Respondents were given an open textbox to respond to the probing question. Of the three assigned learning outcomes, two were always

the same: Numeracy and Science's Impact on Society. The third was a randomly assigned learning outcome from one of the four remaining competencies (Process of Science, Modeling, Interdisciplinary Nature of Science, or Communication & Collaboration).

Two coders (A.W.C and D.D.) qualitatively coded the nature of the probing responses. For the instructor survey, all three probe responses for all instructor-course combinations that were included in the final dataset (i.e. after data cleaning) were coded (345 total probe responses coded). There was a 2.3% non-response rate across probing questions for the instructor survey (eight of 353 responses). For the student survey, there were a total of 786 probe responses across the 262 student-course combinations in the student dataset after cleaning, only two of which were skipped (0.25% non-response rate). Just one probe response was coded per student-course combination. To maximize the breadth of responses analyzed, we chose the randomly assigned learning outcome probe responses for coding, but replaced a randomly selected subset with responses from Numeracy and Science's Impact on Society.

We used the constant comparative method to code web probing responses (Glaser, 1965). Specifically, both coders reviewed a subset of responses to identify themes, and then discussed until consensus was reached on the most representative themes. We identified four non-mutually exclusive codes. We interpreted three of these codes as representing valid response processes, aligned with the intended meaning and purpose of the survey: (1) responses that included counting or other time estimation ("three labs", "nearly every lecture"); (2) responses that recalled specific course topics or student work relating to that learning outcome ("during the unit on ecosystems", "the final project includes this"); (3) responses that justified response based on the nature of the course ("this is a biostatistics course and so numeracy is the primary goal"). The fourth code was for responses with evidence of some type of survey error ("I'm not sure what the learning outcome means", "I briefly touch on this in many class sessions, which in total adds up to one class session") (Tourangeau, Rips, & Rasinski, 2000). Both coders coded all probe responses included in the analysis (i.e. 345 and 262 responses for the instructor and student surveys, respectively). After individual coding, all responses coded with one of the three codes representing valid response processes were pooled into a single "valid response process" code. This pooling was done because we were only interested in whether respondents used valid response processes, not which valid response process they used. We then compared "valid response process" and "survey error" coding and discussed any discrepancies until we came to consensus. Prior to reconciliation, we agreed on 95% and 92.5% of "valid response process" codes and 92% and 85% of "survey error" codes for the instructor and student survey responses, respectively.

We found that the vast majority of respondents used valid response processes (96.2% of instructor responses, 91.7% of student responses) and that responses indicating survey error were relatively uncommon (10.4% of instructor responses, 15.9% of student responses) (Supplemental Table 1). We did not exclude responses coded with survey error due to web probing responses from the final data set unless there was a secondary corroborating reason to believe the response was wholly invalid and should be discarded (e.g., survey was completed in too short of time) as described below in Data Cleaning sections.

We then isolated the probe responses with survey error and examined them for themes. Note that use of this code was not mutually exclusive with a valid response process code (8.7% and 7.6% of instructor and student probe responses were coded with both valid and invalid response processes, respectively). Among responses with evidence of survey error, the majority of these cases corresponded to difficulty in mapping infrequent intermittent teaching to the given response options. For example, “I touch on Science’s Impact on Society briefly about once a week. Since each of these cases are short, they add up to one class session”. This response indicates that the response options may not be appropriate for brief lessons. This error likely led to a more conservative estimation of teaching. The second most common type of survey error involved difficulty mapping responses that fell in between “a few class sessions” and “about half of class sessions”. In courses taught in a semester system, where courses may have a total of ~45 class sessions, ten class sessions would be more than a few but less than half.

### **Notes on Future Use of the BioSkills Curriculum Survey**

Departments that are planning to use the BioSkills Curriculum Survey may want to consider tailoring the survey for their specific purposes. For example, future users may want to increase or decrease the number of teaching frequency options given. Our results showed that the option “one class session” was rarely selected relative to “not taught” and “a few class sessions”. In addition, probing responses indicated that some instructors, especially those who taught on a semester system, wished for an option in between “a few” and “about half of class sessions”. Thus, we would propose to combine “one” and “a few class sessions” to “one or a few class sessions” and then add a response option in between this option and “about half of class sessions”. Finally, our analysis of probing questions revealed that some instructors were uncertain how to respond for learning outcomes that are taught for short periods of time in many class sessions (i.e. whether to report all of the instances (“most class sessions”) or whether to “add up” the instances and report the summed time (“one class session”)). This likely led to a more conservative estimate of teaching frequency for these learning outcomes. Clarifying language could be included in the survey instructors to reduce this issue.

### **Additional Details about Survey Data Cleaning**

#### **Instructor Survey**

As described in Methods, approximately 112 instructors across the five departments initiated the survey. The exact number of unique instructors who initiated the survey cannot be determined because instructors in two of the five departments completed the survey anonymously and thus may be counted more than once if they started a new survey session to report on additional courses (e.g., they reported on a first course from their work computer and a second course from their home computer). This initial dataset included 215 instructor-course combinations, which is defined as a particular instructor reporting on a particular course.

Of the 215 initial instructor-course combinations, nine instructor-course combinations did not include responses to any questions about teaching or assessment, and ten instructor-course combinations included teaching frequency responses for ten or fewer learning outcomes (out

of 20 total possible). Of the ten partial responses, nine were cases where instructors left the survey early (breakoffs) and therefore missing data is MCAR because competencies were presented in random order. These 19 incomplete instructor-course combinations were removed from the dataset.

Of the remaining 196 instructor-course combinations, an additional nine instructor-course combinations were removed for one or more of the following reasons: the instructor reported on only a lab component when the course was determined to include both lecture and lab, the course was not in a biology department, the course was exclusively or primarily graduate level. We also checked all responses for evidence of invalid response processes, such as the use of only one response option (i.e. straight-lining) or taking less time to complete the survey relative to the time we determined it took to read every question. We found no evidence of invalid responses of this sort among instructors.

The final instructor dataset included 187 instructor-course combinations. Among this set, only two instructor-course combinations contained missing data for teaching frequency: one instructor-course combination had missing data for whether a learning outcome was assessed, and six instructor-course combinations had missing data for how a learning outcome was assessed. In all cases, the learning outcomes with missing data were different.

### **Student Survey**

As described in Methods, 10 biology instructors in one department invited their students to complete the survey (306 enrolled students). The initial student dataset included 270 student-course combinations (a particular student reporting on a particular course). The 10 instructors included two who were teaching different sections of a course-based undergraduate research experience course with shared lecture and exams but separate lab sections. These were treated as separate courses since the course was lab-focused and labs were run independently by the two instructors. Additionally, we anticipated that a survey about competencies was likely to elicit reflection on experiences in lab.

Of the 270 initial student-course combinations, eight were removed for one or more of the following reasons: using only one response option (i.e. straight-lining) in combination with not responding to any web probing questions, taking less than three minutes to complete the survey (3.5 minutes was determined to be the minimum amount of time required to read all survey questions), not responding to over half of assigned questions, or completing the survey twice for the same course (student was identified by name; both instances were removed). The final dataset included 262 student-course combinations. There was no missing data (i.e. skipped survey questions) in the final student dataset.

### **Additional Details on Modeling**

#### **Model Design, Parameters, and Evaluation of Fit**

We fit logistic regression models because each of our outcome variables (i.e. whether or not a learning outcome was: reported taught, reported assessed, or reported assessed with a

particular mode) were binary. We fit multilevel models to account for clustering in our data (multiple responses regarding a particular course, multiple responses from a given respondent, multiple learning outcomes within each core competency). Random effects account for particular features of the data. The course random effects allowed us to “borrow strength” across implementations – small departments – while honoring the amount of information provided by each. The respondent random effect accounts for the repeated measures nature of the data wherein each respondent answered multiple questions, which were all included in the model (i.e. responses for each of the 20 learning outcomes). The learning outcome random effect accounts for the inherent nested structure of the data, accounting for different intercepts of each learning outcome. We fit these models in a Bayesian framework because understanding the variation within and across each predictor variable (e.g., Process of Science vs. Quantitative Reasoning) was paramount to our research questions. By summarizing Bayesian posterior probabilities, we increased accuracy of comparisons between multiple groups (Gelman & Hill, 2007).

For most models we used the default, weakly informative priors of mean 0 and sd 2.5. There were a few models for which the outcome variable and data structure combination benefitted from more informative priors. In those cases, we used priors of mean 0 and sd 1. We ran four parallel MCMC chains of 1,000 each. Each model also included burn-in time of 1,000 iterations, which was sufficient to ensure convergence, as judged by visual inspection of chain histories (via the *shinystan* R package (Muth et al., 2018)) and the Gelman-Rubin statistic ( $R_{hat} \approx 1$  for all parameters in all models (Brooks & Gelman, 1998)). We checked model fit by comparing posterior predictions to unmodeled data (Supplemental Figure 2) and by examining the Pareto  $k$  distribution and standard deviation of the random effects (Supplemental Table 4; see below for details of two models that had suboptimal Pareto  $k$  distributions).

## **Pareto $k$**

Pareto  $k$  is an estimate useful in the importance sampling process. Pareto  $k$  estimates how far an individual leave-one-out distribution is from the full distribution. If leaving one observation out changes the posterior distribution substantially, the importance sampling cannot generate reliable estimates. Pareto  $k$  values of  $>0.5$  and  $<0.7$  indicate that the accuracy of the importance sampling is lower but still ok; Pareto  $k$  values  $>0.7$  indicate that the importance sampling does not generate a useful estimate when that observation is left out (see Vehtari et al., 2020 for details). All Pareto  $k$  values were good ( $k < 0.5$ ) for seven of the ten models, indicating great fit of each of those models. The number of Pareto  $k$  values above 0.5 (“ok”) or 0.7 (“bad”) are shown in Supplemental Table 4. Specifically, Model 2c had one “ok” value, Model 4 had 24 “ok” values and 3 “bad” values, and Model 5 had 14 “ok” values. For Models 4 and 5, we determined that the suboptimal results were caused by the uneven distribution of the response variable (i.e. reporting the use of exams or writing, presentations, or projects as an assessment mode) within particular levels of the course and respondent random effects. This arose because the dataset used for Models 4 and 5 only included instructor-course combinations where a learning outcome was reported both taught and assessed. In this reduced dataset, some courses or respondents reported assessment with only one assessment mode (e.g., a course that only uses

exams for assessment or a respondent who never uses writing, presentations, or projects). By refitting Models 4 and 5 removing random effects for course and respondent, the Pareto k values returned to “good” values. The results of these models were qualitatively equivalent in direction and magnitude to the results of the models with all three random effects. We chose to present the data of the models with all three random effects since they better control for non-independence within the data and therefore should be better estimates.

## References

- Burstein, L., McDonnell, L. M., Van Winkle, J., Ormseth, T., Mirocha, J., & Guiton, G. (1995). *Validating National Curriculum Indicators*. Santa Monica, CA: RAND Corporation. Retrieved from [https://www.rand.org/pubs/monograph\\_reports/MR658.html](https://www.rand.org/pubs/monograph_reports/MR658.html)
- Clemmons, A. W., Timbrook, J., Herron, J. C., & Crowe, A. J. (2020). BioSkills Guide: Development and National Validation of a Tool for Interpreting the *Vision and Change* Core Competencies. *CBE—Life Sciences Education*, *19*(4), ar53. <https://doi.org/10.1187/cbe.19-11-0259>
- Desimone, L. M. (2009). Improving Impact Studies of Teachers’ Professional Development: Toward Better Conceptualizations and Measures. *Educational Researcher*, *38*(3), 181–199. <https://doi.org/10.3102/0013189X08331140>
- Gelman, A., & Hill, J. (2007). *Data Analysis Using Regression and Multilevel/Hierarchical Models*. *Data Analysis Using Regression and Multilevel/Hierarchical Models*. New York, NY: Cambridge University Press. <https://doi.org/10.1017/cbo9780511790942>
- Glaser, B. G. (1965). The Constant Comparative Method of Qualitative Analysis. *Social Problems*, *12*(4), 436–445. <https://doi.org/10.2307/798843>
- Marbach-Ad, G., McAdams, K. C., Benson, S., Briken, V., Cathcart, L., Chase, M., ... Smith, A. C. (2010). A Model for Using a Concept Inventory as a Tool for Students’ Assessment and Faculty Professional Development. *CBE—Life Sciences Education*, *9*(4), 408–416. <https://doi.org/10.1187/cbe.10-05-0069>
- Muth, C., Oravecz, Z., & Gabry, J. (2018). User-friendly Bayesian regression modeling: A tutorial with rstanarm and shinystan. *The Quantitative Methods for Psychology*, *14*(2), 99–102. <https://doi.org/10.20982/tqmp.14.2.p099>
- Porter, A. C. (2002). Measuring the Content of Instruction: Uses in Research and Practice. *Educational Researcher*, *31*(7), 3–14. Retrieved from <http://www.project2061.org/>
- Tourangeau, R., Rips, L. J., & Rasinski, K. (2000). *The Psychology of Survey Response*. *The Psychology of Survey Response*. Cambridge: Cambridge University Press. <https://doi.org/10.1017/cbo9780511819322>
- Vehtari, A., Gabry, J., Magnusson, M., Yao, Y., Bürkner, P., Paananen, T., & Gelman, A. (2020). loo: Efficient leave-one-out cross-validation and WAIC for Bayesian models. Retrieved from <https://mc-stan.org/loo/>
- Willis, G. B. (1999). *Cognitive Interviewing. A “how to” guide*. 1999 Meeting of the American Statistical Association. Research Triangle Park, NC.



## **Supplemental Material 5. BioSkills Curriculum Survey for Instructors.**

Questionnaire used to gather data on instructor perceptions of teaching and assessment of core competencies for RQ1, RQ2, and RQ3. Survey logic presented competencies as blocks in a random order. All web probing questions are shown, but survey logic dictated that respondents were only shown three total probing questions.

The version of the questionnaire administered in Department E is shown. The questionnaire varied slightly across departments, depending on preference of pilot collaborator (welcome pages were customized, number of courses instructors were asked to report on varied from 2-7, course characteristics questions varied as described in methods).

## Instructions

### Instructions:

You will be asked how frequently, if at all, you teach certain scientific and workplace skills in your course(s). Please note that not every skill can or should be taught in every course, and most courses will include content, concepts, attitudes, and other goals that are not addressed in this survey. For skills that are taught in your course, you will also be asked about assessment.

The data will be combined with data from other courses in the department to better understand the opportunities our undergraduates have to gain these skills throughout their education. The data will **not** be used for individual evaluation of courses or instructors.

You will also occasionally be asked to explain your responses. Your responses will be used to improve the survey for future use.

Please enter your name.

You will be asked to report on skills taught in each course you have taught in the last two years. Your responses will be automatically saved as you progress through the survey.

You do **not** need to provide information about: non-majors courses (100-level), independent study and research courses (300, 395, 400, 494, 495), seminar participation, internships, and teaching practicum courses (444, 496, 498), or graduate level courses (500+).

Enter the course number of an undergraduate biology course you have taught in the last two years (e.g., 204).

BIOL

You are welcome to report on skills teaching in any components of this course that you are sufficiently familiar with. Which components of this course will you be reporting on? (select all that apply)

- Lecture
- Lab
- Field
- Other (please specify)

Which of the following best describes the primary focus of this course? (please select one)

- Ecology/Evolutionary Biology
- Microbiology
- Molecular/Cellular/Developmental Biology
- Physiology/Anatomy/Organismal Biology
- General Biology
- Other (please specify):

## PS1

Please answer the following questions based on the **most recent time** that you taught **BIOL**{q://QID1/ChoiceTextEntryValue/1}.

For a list of all 20 skills included in this survey, [click here](#).

### **Scientific Thinking: Explain how science generates knowledge of the natural world.**

Hover here for a few examples.  
.....

How frequently is **Scientific Thinking** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Scientific Thinking** assessed in this course?

- Yes
- No

How is **Scientific Thinking** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

### **Information Literacy: Locate, interpret, and evaluate scientific information.**

Hover here for a few examples.  
.....

How frequently is **Information Literacy** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Information Literacy** assessed in this course?

- Yes
- No

How is **Information Literacy** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

**Question Formulation: Pose testable questions and hypotheses to address gaps in knowledge.**

Hover here for a few examples.

How frequently is **Question Formulation** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Question Formulation** assessed in this course?

- Yes
- No

How is **Question Formulation** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

**Study Design: Plan, evaluate, and implement scientific investigations.**

Hover here for a few examples.  
.....

How frequently is **Study Design** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Study Design** assessed in this course?

- Yes
- No

How is **Study Design** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

**Data Interpretation & Evaluation: Interpret, evaluate, and draw conclusions from data in order to make evidence-based arguments about the natural world.**

Hover here for a few examples.  
.....

How frequently is **Data Interpretation & Evaluation** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions

Almost every class session

Is **Data Interpretation & Evaluation** assessed in this course?

- Yes  
 No

How is **Data Interpretation & Evaluation** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

**Doing Research: Apply science process skills to address a research question in a course-based or independent research experience.**

Hover here for a few examples.

How frequently is **Doing Research** taught in this course?

- Not taught  
 One class session  
 A few class sessions  
 About half of class sessions  
 Most class sessions  
 Almost every class session

Is **Doing Research** assessed in this course?

- Yes  
 No

How is **Doing Research** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

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## **PS probe**

Your response to the following question will be used to improve the survey for future use. Your time and feedback is greatly appreciated.

You will only be asked to answer this type of question three times total.

Please explain how you decided to  
select **#{q://QID347/ChoiceGroup/SelectedChoices}** for the following skill:

Scientific Thinking: Explain how science generates knowledge of the natural world.

Please explain how you decided to  
select **#{q://QID350/ChoiceGroup/SelectedChoices}** for the following skill:

Information Literacy: Locate, interpret, and evaluate scientific information.

Please explain how you decided to  
select **#{q://QID353/ChoiceGroup/SelectedChoices}** for the following skill:

Question Formulation: Pose testable questions and hypotheses to address gaps in knowledge.



Please explain how you decided to select **#{q://QID356/ChoiceGroup/SelectedChoices}** for the following skill:

Study Design: Plan, evaluate, and implement scientific investigations.

Please explain how you decided to select **#{q://QID360/ChoiceGroup/SelectedChoices}** for the following skill:

Data Interpretation & Evaluation: Interpret, evaluate, and draw conclusions from data in order to make evidence-based arguments about the natural world.

Please explain how you decided to select **#{q://QID363/ChoiceGroup/SelectedChoices}** for the following skill:

Doing Research: Apply science process skills to address a research question in a course-based or independent research experience.

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## QR1

Please answer the following questions based on the **most recent time** that you taught **BIOL**{q://QID1/ChoiceTextEntryValue/1}.

For a list of all 20 skills included in this survey, [click here](#).

### **Numeracy: Use basic mathematics (e.g., algebra, probability, unit conversions) in biological contexts.**

Hover here for a few examples.  
.....

How frequently is **Numeracy** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Numeracy** assessed in this course?

- Yes
- No

How is **Numeracy** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

### **Quantitative & Computational Data Analysis: Apply the tools of graphing, statistics, and data science to analyze biological data.**

Hover here for a few examples.  
.....

How frequently is **Quantitative & Computational Data Analysis** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Quantitative & Computational Data Analysis** assessed in this course?

- Yes
- No

How is **Quantitative & Computational Data Analysis** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

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### QR probe

Your response to the following question will be used to improve the survey for future use. Your time and feedback is greatly appreciated.

You will only be asked to answer this type of question three times total.

Please explain how you decided to

select **`{q://QID233/ChoiceGroup/SelectedChoices}`** for the following skill:

Numeracy: Use basic mathematics (e.g., algebra, probability, unit conversions) in biological contexts.

Please explain how you decided to select **#{q://QID75/ChoiceGroup/SelectedChoices}** for the following skill:

Quantitative & Computational Data Analysis: Apply the tools of graphing, statistics, and data science to analyze biological data.

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## MS1

Please answer the following questions based on the **most recent time** that you taught **BIOL#{q://QID1/ChoiceTextEntryValue/1}**.

For a list of all 20 skills included in this survey, [click here](#).

**Purpose of Models: Recognize the important roles that scientific models, of many different types (conceptual, mathematical, physical, etc.), play in predicting and communicating biological phenomena.**

Hover here for a few examples.  
.....

How frequently is **Purpose of Models** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions

Almost every class session

Is **Purpose of Models** assessed in this course?

- Yes  
 No

How is **Purpose of Models** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

**Model Application: Make inferences and solve problems using models and simulations.**

Hover here for a few examples.

How frequently is **Model Application** taught in this course?

- Not taught  
 One class session  
 A few class sessions  
 About half of class sessions  
 Most class sessions  
 Almost every class session

Is **Model Application** assessed in this course?

- Yes  
 No

How is **Model Application** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

**Modeling: Build and evaluate models of biological systems.**

Hover here for a few examples.

---

How frequently is **Modeling** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Modeling** assessed in this course?

- Yes
- No

How is **Modeling** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

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**MS probe**

Your response to the following question will be used to improve the survey for future use. Your time and feedback is greatly appreciated.

You will only be asked to answer this type of question three times total.

Please explain how you decided to

select **#{q://QID322/ChoiceGroup/SelectedChoices}** for the following skill:

Purpose of Models: Recognize the important roles that scientific models, of many different types (conceptual, mathematical, physical, etc.), play in predicting and communicating biological phenomena.

Please explain how you decided to

select **#{q://QID325/ChoiceGroup/SelectedChoices}** for the following skill:

Model Application: Make inferences and solve problems using models and simulations.

Please explain how you decided to

select **#{q://QID328/ChoiceGroup/SelectedChoices}** for the following skill:

Modeling: Build and evaluate models of biological systems.

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**ID1**

Please answer the following questions based on the **most recent time** that you taught **BIOL**#{q://QID1/ChoiceTextEntryValue/1}.

For a list of all 20 skills included in this survey, [click here](#).

**Connecting Scientific Knowledge: Integrate concepts across other STEM disciplines (e.g., chemistry, physics) and multiple fields of biology (e.g., cell biology, ecology).**

Hover here for a few examples.  
.....

How frequently is **Connecting Scientific Knowledge** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Connecting Scientific Knowledge** assessed in this course?

- Yes
- No

How is **Connecting Scientific Knowledge** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

**Interdisciplinary Problem Solving: Consider interdisciplinary solutions to real-world problems.**

Hover here for a few examples.  
.....

How frequently is **Interdisciplinary Problem Solving** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions



Almost every class session

Is **Interdisciplinary Problem Solving** assessed in this course?

Yes

No

How is **Interdisciplinary Problem Solving** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

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### **ID probe**

Your response to the following question will be used to improve the survey for future use. Your time and feedback is greatly appreciated.

You will only be asked to answer this type of question three times total.

Please explain how you decided to select **#{q://QID314/ChoiceGroup/SelectedChoices}** for the following skill:

Connecting Scientific Knowledge: Integrate concepts across other STEM disciplines (e.g., chemistry, physics) and multiple fields of biology (e.g., cell biology, ecology).

Please explain how you decided to select **#{q://QID317/ChoiceGroup/SelectedChoices}** for the following skill:

Interdisciplinary Problem Solving: Consider interdisciplinary solutions to real-world problems.

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## CC1

Please answer the following questions based on the **most recent time** that you taught **BIOL#{q://QID1/ChoiceTextEntryValue/1}**.

For a list of all 20 skills included in this survey, [click here](#).

**Communication: Share ideas, data, and findings with others clearly and accurately.**

Hover here for a few examples.  
.....

How frequently is **Communication** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Communication** assessed in this course?

- Yes
- No

How is **Communication** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

**Collaboration: Work productively in teams with people who have diverse backgrounds, skill sets, and perspectives.**

Hover here for a few examples.  
.....

How frequently is **Collaboration** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Collaboration** assessed in this course?

- Yes
- No

How is **Collaboration** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

**Collegial Review: Provide and respond to constructive feedback in order to improve individual and team work.**

Hover here for a few examples.  
.....

How frequently is **Collegial Review** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Collegial Review** assessed in this course?

- Yes
- No

How is **Collegial Review** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

**Metacognition: Reflect on your own learning, performance, and achievements.**

Hover here for a few examples.

How frequently is **Metacognition** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Metacognition** assessed in this course?

- Yes
- No

How is **Metacognition** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

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### **CC probe**

Your response to the following question will be used to improve the survey for future use. Your time and feedback is greatly appreciated.

You will only be asked to answer this type of question three times total.

Please explain how you decided to select **#{q://QID333/ChoiceGroup/SelectedChoices}** for the following skill:

Communication: Share ideas, data, and findings with others clearly and accurately.

Please explain how you decided to select **#{q://QID336/ChoiceGroup/SelectedChoices}** for the following skill:

Collaboration: Work productively in teams with people who have diverse backgrounds, skill sets, and perspectives.

Please explain how you decided to select **#{q://QID339/ChoiceGroup/SelectedChoices}** for the following skill:

Collegial Review: Provide and respond to constructive feedback in order to improve individual and team work.

Please explain how you decided to select **#{q://QID343/ChoiceGroup/SelectedChoices}** for the following skill:

Metacognition: Reflect on your own learning, performance, and achievements.

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## SS1

Please answer the following questions based on the **most recent time** that you taught **BIOL#{q://QID1/ChoiceTextEntryValue/1}**.

For a list of all 20 skills included in this survey, [click here](#).

**Ethics: Demonstrate the ability to critically analyze ethical issues in the conduct of science.**

Hover here for a few examples.  
.....

How frequently is **Ethics** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Ethics** assessed in this course?

- Yes
- No

How is **Ethics** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

**Societal Influences: Consider the potential impacts of outside influences (historical, cultural, political, technological) on how science is practiced.**

Hover here for a few examples.  
.....

How frequently is **Societal Influences** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Societal Influences** assessed in this course?

- Yes
- No

How is **Societal Influences** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

**Science's Impact on Society: Apply scientific reasoning in daily life and recognize the impacts of science on a local and global scale.**

Hover here for a few examples.

How frequently is **Science's Impact on Society** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

Is **Science's Impact on Society** assessed in this course?

- Yes
- No

How is **Science's Impact on Society** assessed in this course (e.g., free-response exam questions, lab reports, homework assignments)?

**These page timer metrics will not be displayed to the recipient.**

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**SS probe**

Your response to the following question will be used to improve the survey for future use. Your time and feedback is greatly appreciated.



You will only be asked to answer this type of question three times total.

Please explain how you decided to

select **#{q://QID264/ChoiceGroup/SelectedChoices}** for the following skill:

Ethics: Demonstrate the ability to critically analyze ethical issues in the conduct of science.

Please explain how you decided to

select **#{q://QID267/ChoiceGroup/SelectedChoices}** for the following skill:

Societal Influences: Consider the potential impacts of outside influences (historical, cultural, political, technological) on how science is practiced.

Please explain how you decided to

select **#{q://QID273/ChoiceGroup/SelectedChoices}** for the following skill:

Science's Impact on Society: Apply scientific reasoning in daily life and recognize the impacts of science on a local and global scale.

**These page timer metrics will not be displayed to the recipient.**

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Click Count: *0 clicks*

## Restart1

Optional: Please share any other skills taught in this course that should be considered in our curriculum review.

Optional: Please share any other comments on this course.

## Have you taught any other undergraduate biology courses in the past two years?

You do **not** need to provide information about: non-majors courses (100-level), independent study and research courses (300, 395, 400, 494, 495), seminar participation, internships, and teaching practicum courses (444, 496, 498), or graduate level courses (500+).

*Note that if you do not have time to complete the survey now, your progress from this session is saved in your browser. To access in-progress survey, simply follow survey link using the same computer and browser. Alternatively, if you prefer to complete the survey from multiple computers, you may also submit this survey and start a new session later.*

- Yes, I have taught another course  
 No, exit the survey

Enter the course number of another undergraduate biology course you have taught in the last two years (e.g., 204).

BIOL

## **Supplemental Material 6. BioSkills Curriculum Survey for Students.**

Questionnaire used to gather data on student perceptions of teaching of core competencies for RQ3. Survey logic presented competencies in a random order. All web probing questions are shown, but survey logic dictated that respondents were only shown three total probing questions. The questionnaire did not vary across courses.

## Welcome

At ██████████ we are always striving to improve the education we offer to students. This year we are paying particular attention to the *skills* being taught in our courses.

As a student in our biology program, we want to hear about your experience. **We are asking you to take a ~15 minute survey** to share your thoughts on the skills that you developed in BIOL340. The survey will remain open until 5 p.m. Monday, December 9th.

**Participation in the survey is voluntary.** After the survey is complete, a list of all students who completed the survey (but not their answers) will be given to the instructor so that you can receive points for completing the survey. Responses will then have the names removed, and results of the survey will be summarized before being reported. The results will be used as part of a larger effort to better understand skills training in our program. Results will also be used by education researchers to learn about improvement efforts such as this.

Thank you very much for your help!

### Instructions:

You will be asked how frequently, if at all, certain scientific and workplace skills were taught in BIOL340.

You will also occasionally be asked to explain your responses. Your responses to these questions will be used to improve the survey for future use.

Please enter your name. (This will only be used so that you can be given points for completing this survey. Your name will not be linked with any of your responses.)

### PS1

Please answer the following questions based on your experiences in **BIOL340**.

**Scientific Thinking: Explain how science generates knowledge of the natural world.**

Hover here for a few examples.  
.....

How frequently was **Scientific Thinking** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Information Literacy: Locate, interpret, and evaluate scientific information.**

Hover here for a few examples.  
.....

How frequently was **Information Literacy** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Question Formulation: Pose testable questions and hypotheses to address gaps in knowledge.**

Hover here for a few examples.  
.....

How frequently was **Question Formulation** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Study Design: Plan, evaluate, and implement scientific investigations.**

Hover here for a few examples.  
.....

How frequently was **Study Design** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Data Interpretation & Evaluation: Interpret, evaluate, and draw conclusions from data in order to make evidence-based arguments about the natural world.**

Hover here for a few examples.  
.....

How frequently was **Data Interpretation & Evaluation** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Doing Research: Apply science process skills to address a research question in a course-based or independent research experience.**

Hover here for a few examples.  
.....

How frequently was **Doing Research** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

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**PS probe**

Your response to the following question will be used to improve the survey for future use. Your time and feedback is greatly appreciated.

You will only be asked to answer this type of question three times total.

Please explain how you decided to select **#{q://QID347/ChoiceGroup/SelectedChoices}** for the following skill:

Scientific Thinking: Explain how science generates knowledge of the natural world.

Please explain how you decided to select **#{q://QID350/ChoiceGroup/SelectedChoices}** for the following skill:

Information Literacy: Locate, interpret, and evaluate scientific information.

Please explain how you decided to select **#{q://QID353/ChoiceGroup/SelectedChoices}** for the following skill:

Question Formulation: Pose testable questions and hypotheses to address gaps in knowledge.

Please explain how you decided to  
select **#{q://QID356/ChoiceGroup/SelectedChoices}** for the following skill:

Study Design: Plan, evaluate, and implement scientific investigations.

Please explain how you decided to  
select **#{q://QID360/ChoiceGroup/SelectedChoices}** for the following skill:

Data Interpretation & Evaluation: Interpret, evaluate, and draw conclusions from data  
in order to make evidence-based arguments about the natural world.

Please explain how you decided to  
select **#{q://QID363/ChoiceGroup/SelectedChoices}** for the following skill:

Doing Research: Apply science process skills to address a research question in a  
course-based or independent research experience.

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## QR1

Please answer the following questions based on your experiences in **BIOL340**.



**Numeracy: Use basic mathematics (e.g., algebra, probability, unit conversions) in biological contexts.**

Hover here for a few examples.  
.....

How frequently was **Numeracy** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Quantitative & Computational Data Analysis: Apply the tools of graphing, statistics, and data science to analyze biological data.**

Hover here for a few examples.  
.....

How frequently was **Quantitative & Computational Data Analysis** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

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**QR probe**

Your response to the following question will be used to improve the survey for future use. Your time and feedback is greatly appreciated.

You will only be asked to answer this type of question three times total.

Please explain how you decided to select **#{q://QID233/ChoiceGroup/SelectedChoices}** for the following skill:

Numeracy: Use basic mathematics (e.g., algebra, probability, unit conversions) in biological contexts.

Please explain how you decided to select **#{q://QID75/ChoiceGroup/SelectedChoices}** for the following skill:

Quantitative & Computational Data Analysis: Apply the tools of graphing, statistics, and data science to analyze biological data.

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## MS1

Please answer the following questions based on your experiences in **BIOL340**.

**Purpose of Models: Recognize the important roles that scientific models, of many different types (conceptual, mathematical, physical, etc.), play in predicting and communicating biological phenomena.**

Hover here for a few examples.  
.....

How frequently was **Purpose of Models** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Model Application: Make inferences and solve problems using models and simulations.**

Hover here for a few examples.  
.....

How frequently was **Model Application** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Modeling: Build and evaluate models of biological systems.**

Hover here for a few examples.  
.....

How frequently was **Modeling** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

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**MS probe**

Your response to the following question will be used to improve the survey for future use. Your time and feedback is greatly appreciated.

You will only be asked to answer this type of question three times total.

Please explain how you decided to select **#{q://QID322/ChoiceGroup/SelectedChoices}** for the following skill:

Purpose of Models: Recognize the important roles that scientific models, of many different types (conceptual, mathematical, physical, etc.), play in predicting and communicating biological phenomena.

Please explain how you decided to select **#{q://QID325/ChoiceGroup/SelectedChoices}** for the following skill:

Model Application: Make inferences and solve problems using models and simulations.

Please explain how you decided to select **#{q://QID328/ChoiceGroup/SelectedChoices}** for the following skill:

Modeling: Build and evaluate models of biological systems.

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## ID1

Please answer the following questions based on your experiences in **BIOL340**.

**Connecting Scientific Knowledge: Integrate concepts across other STEM disciplines (e.g., chemistry, physics) and multiple fields of biology (e.g., cell biology, ecology).**

Hover here for a few examples.  
.....

How frequently was **Connecting Scientific Knowledge** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Interdisciplinary Problem Solving: Consider interdisciplinary solutions to real-world problems.**

Hover here for a few examples.  
.....

How frequently was **Interdisciplinary Problem Solving** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

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## ID probe

Your response to the following question will be used to improve the survey for future use. Your time and feedback is greatly appreciated.

You will only be asked to answer this type of question three times total.

Please explain how you decided to select **#{q://QID314/ChoiceGroup/SelectedChoices}** for the following skill:

Connecting Scientific Knowledge: Integrate concepts across other STEM disciplines (e.g., chemistry, physics) and multiple fields of biology (e.g., cell biology, ecology).

Please explain how you decided to select **#{q://QID317/ChoiceGroup/SelectedChoices}** for the following skill:

Interdisciplinary Problem Solving: Consider interdisciplinary solutions to real-world problems.

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## CC1

Please answer the following questions based on your experiences in **BIOL340**.

**Communication: Share ideas, data, and findings with others clearly and accurately.**

Hover here for a few examples.  
.....

How frequently was **Communication** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Collaboration: Work productively in teams with people who have diverse backgrounds, skill sets, and perspectives.**

Hover here for a few examples.  
.....

How frequently was **Collaboration** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Collegial Review: Provide and respond to constructive feedback in order to improve individual and team work.**

Hover here for a few examples.  
.....

How frequently was **Collegial Review** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Metacognition: Reflect on your own learning, performance, and achievements.**

Hover here for a few examples.

How frequently was **Metacognition** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

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### CC probe

Your response to the following question will be used to improve the survey for future use. Your time and feedback is greatly appreciated.

You will only be asked to answer this type of question three times total.

Please explain how you decided to

select **`#{q://QID333/ChoiceGroup/SelectedChoices}`** for the following skill:

Communication: Share ideas, data, and findings with others clearly and accurately.

Please explain how you decided to

select **`#{q://QID336/ChoiceGroup/SelectedChoices}`** for the following skill:

Collaboration: Work productively in teams with people who have diverse backgrounds, skill sets, and perspectives.



Please explain how you decided to select **#{q://QID339/ChoiceGroup/SelectedChoices}** for the following skill:

Collegial Review: Provide and respond to constructive feedback in order to improve individual and team work.

Please explain how you decided to select **#{q://QID343/ChoiceGroup/SelectedChoices}** for the following skill:

Metacognition: Reflect on your own learning, performance, and achievements.

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**SS1**

Please answer the following questions based on your experiences in **BIOL340**.

**Ethics: Demonstrate the ability to critically analyze ethical issues in the conduct of science.**

Hover here for a few examples.

.....

How frequently was **Ethics** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Societal Influences: Consider the potential impacts of outside influences (historical, cultural, political, technological) on how science is practiced.**  
Hover here for a few examples.  
.....

How frequently was **Societal Influences** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

**Science's Impact on Society: Apply scientific reasoning in daily life and recognize the impacts of science on a local and global scale.**  
Hover here for a few examples.  
.....

How frequently was **Science's Impact on Society** taught in this course?

- Not taught
- One class session
- A few class sessions
- About half of class sessions
- Most class sessions
- Almost every class session

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## SS probe

Your response to the following question will be used to improve the survey for future use. Your time and feedback is greatly appreciated.

You will only be asked to answer this type of question three times total.

Please explain how you decided to select **#{q://QID264/ChoiceGroup/SelectedChoices}** for the following skill:

Ethics: Demonstrate the ability to critically analyze ethical issues in the conduct of science.

Please explain how you decided to select **#{q://QID267/ChoiceGroup/SelectedChoices}** for the following skill:

Societal Influences: Consider the potential impacts of outside influences (historical, cultural, political, technological) on how science is practiced.

Please explain how you decided to select **#{q://QID273/ChoiceGroup/SelectedChoices}** for the following skill:

Science's Impact on Society: Apply scientific reasoning in daily life and recognize the impacts of science on a local and global scale.

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**End1**

Optional: Please share any comments about the skills taught in this course.

This is the end of the survey. Thank you for your input!