PROCESS OF SCIENCE

Program-Level Learning Outcomes	Course-Level Learning Outcomes
SCIENTIFIC THINKING Explain how science generates knowledge of the natural world.	Explain how scientists use inference and evidence-based reasoning to generate knowledge.
	Describe the iterative nature of science and how new evidence can lead to the revision of scientific knowledge.
INFORMATION LITERACY Locate, interpret, and evaluate scientific information.	Find and evaluate the credibility of a variety of sources of scientific information, including popular science media and scientific journals.
	Interpret, summarize, and evaluate evidence in primary literature.
	Evaluate claims in scientific papers, popular science media, and other sources using evidence-based reasoning.
QUESTION FORMULATION Pose testable questions and hypotheses to address gaps in knowledge.	Recognize gaps in our current understanding of a biological system or process and identify what specific information is missing.
	Develop research questions based on your own or others' observations.
	Formulate testable hypotheses and state their predictions.
STUDY DESIGN Plan, evaluate, and inplement scientific investigations.	Compare the strengths and limitations of various study designs.
	Design controlled experiments, including plans for analyzing the data.
	Execute protocols and accurately record measurements and observations.
	Identify methodological problems and suggest how to troubleshoot them.
	Evaluate and suggest best practices for responsible research conduct (e.g., lab safety, record keeping, proper citation of sources).
DATA INTERPRETATION & EVALUATION Interpret, evaluate, and draw conclusions from data in order to make evidence-based arguments about the natural world.	Analyze data, summarize resulting patterns, and draw appropriate conclusions.
	Describe sources of error and uncertainty in data.
	Make evidence-based arguments using your own and others' findings.
	Relate conclusions to original hypothesis, consider alternative hypotheses, and suggest future research directions based on findings.
DOING RESEARCH Apply science process skills to address a research question in a course-based or independent research experience.	

QUANTITATIVE REASONING

Program-Level Learning Outcomes	Course-Level Learning Outcomes
NUMERACY Use basic mathematics (e.g., algebra, probability, unit conversion) in biological contexts.	Perform basic calculations (e.g., percentages, frequencies, rates, means).
	Select and apply appropriate equations (e.g., Hardy-Weinberg, Nernst, Gibbs free energy) to solve problems.
	Interpret and manipulate mathematical relationships (e.g., scale, ratios, units) to make quantitative comparisons.
	Use probability and understanding of biological variability to reason about biological processes and statistical analyses.
	Use rough estimates informed by biological knowledge to check quantitative work.
	Describe how quantitative reasoning helps biologists understand the natural world.
QUANTITATIVE & COMPUTATIONAL DATA ANALYSIS Apply the tools of graphing, statistics, and data science to analyze biological data.	Record, organize, and annotate simple data sets.
	Create and interpret informative graphs and other data visualizations.
	Select, carry out, and interpret statistical analyses.
	Describe how biologists answer research questions using databases, large data sets, and data science tools.
	Interpret the biological meaning of quantitative results.

MODELING

Program-Level Learning Outcomes	Course-Level Learning Outcomes
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.	Describe why biologists use simplified representations (models) when solving problems and communicating ideas.
	Given two models of the same biological process or system, compare their strengths, limitations, and assumptions.
MODEL APPLICATION Make inferences and solve problems using models and simulations.	Summarize relationships and trends that can be inferred from a given model or simulation.
	Use models and simulations to make predictions and refine hypotheses.
MODELING Build and evaluate models of biological systems.	Build and revise conceptual models (e.g., diagrams, concept maps, flow charts) to propose how a biological system or process works.
	Identify important components of a system and describe how they influence each other (e.g., positively or negatively).
	Evaluate conceptual, mathematical, or computational models by comparing their predictions with empirical data.

INTERDISCIPLINARY NATURE OF SCIENCE

Program-Level Learning Outcomes	Course-Level Learning Outcomes
CONNECTING SCIENTIFIC KNOWLEDGE Integrate concepts across other STEM disciplines (e.g., chemistry, physics) and multiple fields of biology (e.g., cell biology, ecology).	Given a biological problem, identify relevant concepts from other STEM disciplines or fields of biology.
	Build models or explanations of simple biological processes that include concepts from other STEM disciplines or multiple fields of biology.
INTERDISCIPLINARY PROBLEM SOLVING Consider interdisciplinary solutions to real-world problems.	Describe examples of real-world problems that are too complex to be solved by applying biological approaches alone.
	Suggest how collaborators in STEM & non-STEM disciplines could contribute to solutions of real-world problems.
	Be able to explain biological concepts, data, and methods, including their limitations, using language understandable by collaborators in other disciplines.

COMMUNICATION & COLLABORATION

Program-Level Learning Outcomes	Course-Level Learning Outcomes
COMMUNICATION Share ideas, data, and findings with others clearly and accurately.	Use appropriate language and style to communicate science effectively to targeted audiences (e.g., general public, biology experts, collaborators in other disciplines).
	Use a variety of modes to communicate science (e.g., oral, written, visual).
COLLABORATION Work productively in teams with people who have diverse backgrounds, skill sets, and perspectives.	Work with teammates to establish and periodically update group plans and expectations (e.g., team goals, project timeline, rules for group interactions, individual and collaborative tasks).
	Elicit, listen to, and incorporate ideas from teammates with different perspectives and backgrounds.
	Work effectively with teammates to complete projects.
COLLEGIAL REVIEW Provide and respond to constructive feedback in order to improve individual and team work.	Evaluate feedback from others and revise work or behavior appropriately.
	Critique others' work and ideas constructively and respectfully.
METACOGNITION Reflect on your own learning, performance, and achievements.	Evaluate your own understanding and skill level.
	Assess personal progress and contributions to your team and generate a plan to change your behavior as needed.

SCIENCE & SOCIETY

Program-Level Learning Outcomes	Course-Level Learning Outcomes
ETHICS Demonstrate the ability to critically analyze ethical issues in the conduct of science.	Identify and evaluate ethical considerations (e.g., use of animal or human subjects, conflicts of interest, confirmation bias) in a given research study.
	Critique how ethical controversies in biological research have been and can continue to be addressed by the scientific community.
SOCIETAL INFLUENCES Consider the potential impacts of outside influences (historical, cultural, political, technological) on how science is practiced.	Describe examples of how scientists' backgrounds and biases can influence science and how science is enhanced through diversity.
	Identify and describe how systemic factors (e.g., socioeconomic, political) affect how and by whom science is conducted.
SCIENCE'S IMPACT ON SOCIETY Apply scientific reasoning in daily life and recognize the impacts of science on a local and global scale.	Apply evidence-based reasoning and biological knowledge in daily life (e.g., consuming popular media, deciding how to vote).
	Use examples to describe the relevance of science in everyday experiences.
	Identify and describe the broader societal impacts of biological research on different stakeholders.
	Describe the roles scientists have in facilitating public understanding of science.

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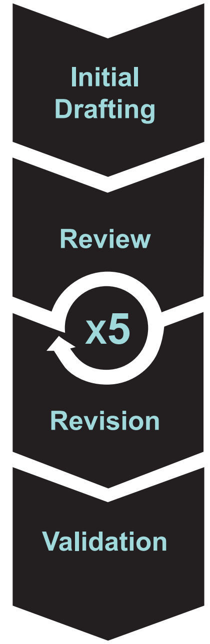
To download or share the BioSkills Guide:
https://qubeshub.org/qubesresources/publications/1305

HOW WAS THE BIOSKILLS GUIDE DEVELOPED?



- Began with faculty-crafted draft
- Literature review
- Interviews
- Workshop

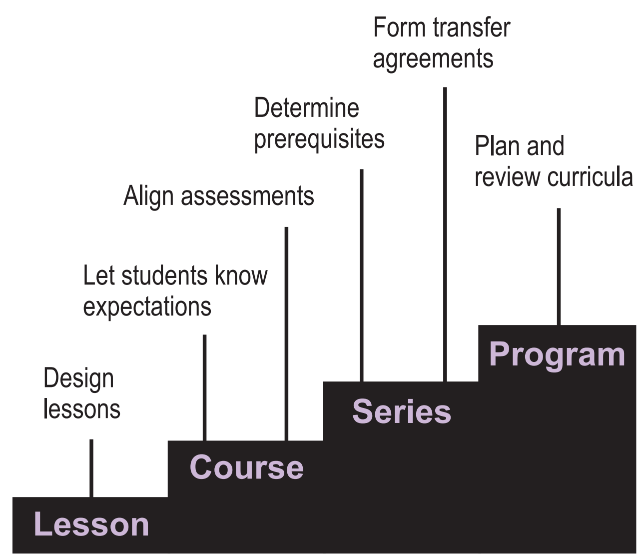
- Surveys
- Interviews
- Workshops

n=218 (~60/outcome)

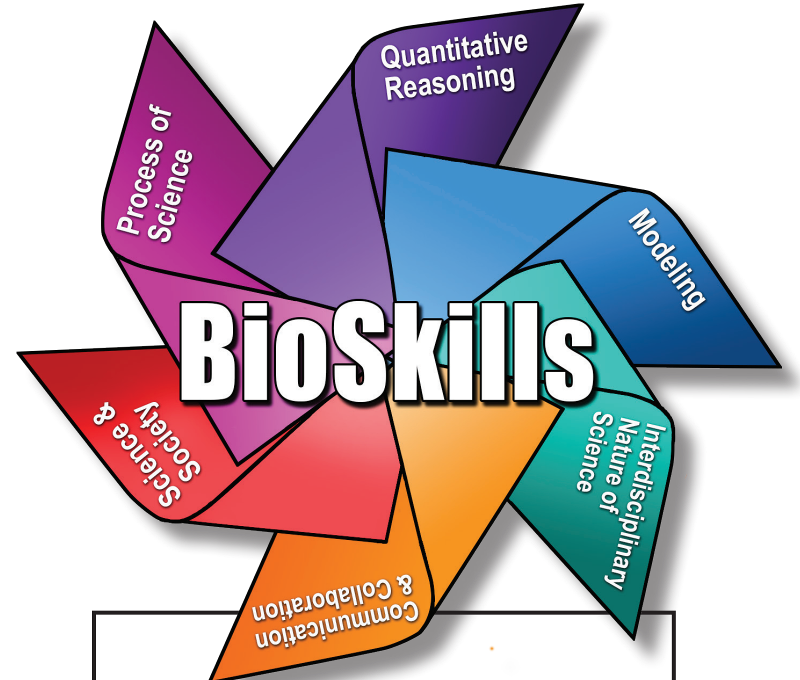
- Survey

n=417 (~210/outcome)

HOW CAN THE BIOSKILLS GUIDE HELP YOU?



A Tool for Interpreting the Vision and Change CORE COMPETENCIES



The BioSkills Guide comprises program- and course-level learning outcomes that elaborate what general biology majors should be able to do by the time they graduate. Building on the six core competencies of Vision and Change, the learning outcomes were developed and then nationally validated using input from over 600 college biology educators from a range of biology subdisciplines and institution types.