Best Practices and Recommendations for Designing Activities for Highlighting Diverse Scientists through Quantitative Skill Development

Kristen A. Butela[1], Pratima Jindal[2], and Sheela Vemu[2]

University of Pittsburgh[1] and Waubonsee Community College[2]

Abstract

Diversity and inclusion efforts in course design include promoting and centering the work of scientists from underrepresented groups in order to foster a sense of belonging in science among students from a variety of diverse backgrounds. However, STEM educators can often face barriers to the design and implementation of these activities due to demands on faculty time, constraints on course material, external concerns about academic rigor, and difficulties in linking course topics with inclusivity elements. In Spring 2021, we participated in the Scientist Spotlight and Data Nuggets Faculty Mentoring Network, a QUBES group dedicated to designing learning activities that focus on quantitative skill development through highlighting the work of scientists from underrepresented groups. The activities present an opportunity for students to use podcasts or written/video interviews to interact with scientists using the framework of quantitative reasoning and the shared experiences of their scientific worldviews. Here, we share best practices on customization and implementation strategies that can cover the overarching goals of designing activities that promote student quantitative skill development and highlighting the work of scientists from underrepresented groups. Integrating diverse scientists' perspectives instills creativity in teaching materials. This creativity emerges from diversity, and that the advantages of diversity are realized only through inclusion of these best practices in a teaching environment. A critical part of inclusion is also about paying attention to students' feelings of belonging and science identity. Our work is an attempt to distill some best practices that we can use as a guide to designing quantitative skill-based learning activities that help to create an inclusive environment with whom we teach, mentor or work in our disciplines.

Introduction

The BioSkills guide, a nationally validated resource based on the *Vision and Change* curriculum recommendations for undergraduate biology education, provides educators with a list of core competencies that can be used to structure course design (Clemmons *et al* 2020). The ability to use quantitative reasoning is a major competency outlined by the BioSkills Guide and is often integrated into the learning outcomes of many biology lab courses. Specific quantitative skills emphasized in biology lab courses include performing basic calculations, using appropriate equations, interpreting graphs and other visualizations of data, and interpreting the meaning of quantitative data. Given the rapid advances in quantitative biology, supporting student learning of quantitative skills is critical to preparing students for careers in biology. However, acquiring these skills is challenging to many students from a variety of backgrounds for several reasons, including the separation of math and biology courses (Gross 2000)(Bialek and Botstein 2004). These challenges are especially relevant to students enrolled in community colleges who face additional barriers, including delayed entry to college, part-time attendance, and starting their education at a higher age than traditional students (Labov 2012)(Community College Research Center, 2020). Inclusion of more quantitative skill development activities into biology lab courses provides an intentional focus on helping students bridge the gap between their math and biology coursework. Quantitative reasoning is only one element of the BioSkills core competencies, as this document is intended to provide a holistic approach to the development of undergraduate biology curriculum. Assignments and activities can take the same approach and blend multiple core competencies in their design.

An often overlooked element of biology laboratory courses is intentional course design with a focus on diversity and inclusion. Core competencies in the Science and Society category of the BioSkills Guide emphasize diversity and inclusion elements, including: the identification and description of how systemic factors affect who becomes a scientist and how the process of science is conducted and describing examples of how scientists' backgrounds and biases can influence science, and explaining how the process of science is enhanced by diversity (Clemmons *et al* 2020). Embedding inclusive practices can promote a supportive climate for improving student motivation and persistence in STEM (Dewsberry 2019). Specifically including representation of counterstereotypical scientists into inclusive teaching practices can promote students' sense of self-efficacy and belonging in science (Alfasi 2003). Lack of representation of diverse scientists, intentional or unintentional, in popular media (Tanner 2009), curriculum materials and faculty (National Science Foundation 2013), and within classrooms (Cheyran 2009) can impact student views on the types of people who become scientists and how they conduct the process of science. Course design with the BioSkills Guide Science and Society core competencies can help to address the lack of representation of diverse scientists present in many biology courses, and Schinske *et al* (2015) has shown that these efforts may actually promote student success in science courses. The use of Scientist Spotlights metacognitive assessments featuring counterstereotypcal scientists in introductory biology courses has been shown to positively impact students' stereotypes of scientists and promote science identity (Schinske 2016).

Scientist Spotlight activities have been used to blend inclusive teaching practices with course content coverage (Schinske 2016), successfully blending multiple BioSkills Core Competencies into a single assignment. We designed a framework that can be used by faculty to develop Scientist Spotlight-type assessments for undergraduate biology courses that pair quantitative skill development activities, such as reading primary literature and interpreting data, with a deliberate focus on the representation of diverse scientists. Through the use of backwards design (McTighe 2003), faculty can build these activities to support the essential quantitative skill development learning outcomes through the lens of inclusive teaching practices that can promote student persistence and success in the course. An emphasis on using primary literature in these assessments provides the necessary rigor and depth that faculty intend for their course design. Our framework is intended to streamline the process of generating quantitative skill development-based Scientist Spotlights to reduce barriers to activity development so that a large repository of similar activities can be built and made available to the scientific teaching community. More quantitative skill-based Scientist Spotlights will be available for faculty to enhance their inclusive teaching practices at a variety of course levels customizable for content and academic rigor.

Scientist Spotlight and Data Nugget Quantitative Assignment Design Workflow Outlines Action Items for Successful Completion

Identify key concept involving quantitative reasoning	• Identify core competencies from the BioSkills Guide related to a frequently misunderstood or difficult concept • Use Backwards Design and write learning outcomes in accessible language
Identify scientists from underrepresented groups working in the concept and select research paper	• Identify scientist who works in relevant field from the Database of Databases of Diverse Speakers in STEM • Select a paper authored by the scientist that is appropriate for course level
Design the assignment	• Prioritize meaningful questions to prioritize the scientist's time and allow for revision • Use BioSkills Guide and course syllabus to write questions about the research paper that map back to learning outcomes
Contact scientist for interview	• Provide assignment to scientist at the time of initial contact so they have a clear idea of expectations, can provide feedback for revision, and can accommodate participation based on changing availability • Plan to make effective use of the interview time
Conduct interview and refine lesson plan	• Select appropriate interview format • Conduct and edit interview • Provide final lesson plan and assignment for scientist to review

Figure 1. Overview of Scientist Spotlight and Data Nugget assignment design workflow. This framework was designed to enable faculty, who are often limited by time and resources, to create assignments that blend quantitative skill development and diversity in STEM courses.

BioSkills Core Competencies and Backwards Design Support Creation of Quantitative Skill Development Learning Outcomes

Backwards Design Approach to Assignment Development	Integrate BioSkills Core Competencies into Design	Write Learning Outcomes for Planned Resources
Backwards design: design the course and assignment with the end learning goals Select concept from a course that is traditionally difficult for students to master or one that frequently is associated with student misconceptions	Select appropriate core competencies from the BioSkills Guide relevant to course	Write learning outcomes that describe what students should be able to do by the end of the course/assignment Accessible language

Figure 2. Development of the Scientist Spotlight and Data Nugget assignment development begins with using backwards design to develop learning outcomes associated with the core competencies from the BioSkills Guide. Mapping the assignment to specific course learning outcomes facilitates coverage of course material so that the activity is meaningful to student learning and can replace existing lessons that are less inclusive.

The Database of Databases of Diverse Speakers in STEM Provides Large Pool of Potential Participants for Scientist Spotlight Element of the Assignment

Identifying a Underrepresented Scientists Working in Concept Area	Select Research Papers Covering the Concept	Create Timeline of Assignment Development
Consult the Databases of Databases of Diverse Speakers in STEM master list Decide to initially focus on the content area or on a scientist from a particular underrepresented group Create a list of 3-4 scientists you want to highlight Scientists who self-nominate for lists may be more likely to participate	Perform literature search for current works by the scientist(s) for paper that fits the following criteria: Appropriate for students at the level of course Provides a venue for quantitative skill-based questions Recommend repeating this process for at least the top two scientists on list	Scientists from underrepresented groups may have many demands upon their time Recommend developing assignment 1-2 semesters before implementation and presenting scientist with the most information on the project and reasonable expectations

Figure 3. Recommendations for selecting appropriate candidates for the Scientist Spotlight portion of the assignment. Scientists from underrepresented groups may have many demands upon their time and their bandwidth may be limited for participating in diversity and inclusion activities. A mindful approach to selecting a scientist involves being aware of the time and emotional costs associated with participation, so having several candidate scientists in the assignment development phase maximizes the chances of completing the project in a reasonable amount of time.

Completing Assignment Development Prior to Contacting Scientists Makes Good Use of Time and Resources

Write Assessment Questions	Select Scientist Interview Questions	Develop Preliminary Lesson Plans	Contact Scientist
Use BioSkills guide and course syllabus to write questions that relate to the research paper	Prioritize meaningful questions for consideration of scientist's time Allow scientists to preview questions and choose ones based on their personal preferences Aim for a 30 minute interview, including brief introduction	Map assignment to content covered in course and any other curriculum guidelines	Allow scientist to preview the lesson plan and assignment before committing to the project so that expectations are clear Scientist availability may move quickly, so having work already done maximizes scheduling opportunities Scientist may offer additional feedback to improve the lesson

Figure 4. Developing the assignment and lesson plan before contacting the scientist provides clear expectations for commitment to the project and allows the scientist to provide valuable feedback for revision. Windows of scientists' availability may vary during the year, and having a completed assignment and list of interview questions for them to review provides them with clear expectations for participation. Approaches to diversity and inclusion should take into account the additional workload and emotional investment of scientists from underrepresented groups who are often asked to participate in diversity and inclusion experiences. Candidate scientists may decline participation in the project for a variety of reasons, so it is important to have backup candidates and take a nonjudgmental, humane approach to scientist selection.

Scientist Interviews can be Conducted in a Variety of Formats to Facilitate Flexibility in Finalizing the Assignment

Choose Interview Format	Conduct Interview	Edit Interview	Final Revision of Assignment
Synchronous or asynchronous Video Podcast Typed responses Accessibility (closed captioned, transcript)	Schedule a time for the interview with the scientist Pilot use of technology prior to the interview Always have a backup plan	Written transcript/closed captions Audio/video editing	Provide final lesson plan and assignment for scientist to review for possible collaboration or co-authorship Activities will be published, so seek consent of scientist before final documents published

Figure 5. Maintaining flexibility with interview format and ensuring that all associated materials are accessible allows for additional inclusivity of the project. Allowing the scientist to review the final project provides time for meaningful feedback and potential collaboration and/or co-authorship, which may be beneficial to the professional development of both the faculty designing the assignment and to the scientist being interviewed.

Project Resources

- Guide to Scientist Spotlight and Data Nugget Assignment Development
- List of scientist interview questions
- Link to Database of Databases of Diverse Speakers in STEM
- Example assignment: Jindal, P., Vemu, S. (2021). Understanding Action Potential and Frequency Coding using Scientist Spotlight and Data Nuggets. Scientists Spotlights and Data Nuggets, QUBES Educational Resources. doi:10.25334/0WWH-BW25

Acknowledgements

We would like to thank the participants of the Spring 2021 QUBES Faculty Mentoring Network: Scientist Spotlight and Data Nuggets group for their feedback and insight.

References

Alfasi, M. (2003) Promoting the will and skill of students at academic risk: An evaluation of an instructional design geared to foster achievement, self-efficacy and motivation. J Instr Psychol 30(1): 28–40.

Bialek W, Botstein D. Introductory science and mathematics education for 21st-Century biologists. Science. 2004 Feb 6; 303(5659): 788-90.

Cheryan S, Plaut VC, Davies PG, Steele CM (2009). Ambient belonging: how stereotypical cues impact gender participation in computer science. J Pers Soc Psychol 97: 1045.

Clemmons AW, Timbrook J, Herron JC, and Crowe AJ. (2020). BioSkills Guide: Development and National Validation of a Tool for Interpreting the Vision and Change Core Competencies. CBE Life Sci Educ 19(4): ar44.

Community College Research Center (2020) Improving Community College Student Transfer and Attainment: Early Momentum Metrics for Formative Evaluation of Community College STEM Transfer Reforms.

Dewsbury B, Brame CJ.(2019). Inclusive Teaching. CBE Life Sci Educ 18(2):fe2.

Jindal, P., Vemu, S. (2021). Understanding Action Potential and Frequency Coding using Scientist Spotlight and Data Nuggets. Scientists Spotlights and Data Nuggets, QUBES Educational Resources.

Labov J. B. (2012). Changing and evolving relationships between two- and four-year colleges and universities: they're not your parents' community colleges anymore. CBE Life Sci Educ 11(2): 121–128.

McTighe, J., & Wiggins, G. (1999). Understanding by design: Handbook. Alexandria, VA: Association for Supervision & Curriculum Development.

McTighe, J., & Thomas, R. (2003). Backward design for forward action. Educational Leadership 60(5): 52-55.

National Science Foundation (2021). Women, Minorities, and Persons with Disabilities in Science and Engineering: 2021 (Special Report NSF 21-321), Arlington, VA: National Center for Science and Engineering Statistics, https://ncses.nsf.gov/pubs/nsf21321(accessed 5 Jul 2021).

Richards JM, Gross JJ.(2000) Emotion regulation and memory: the cognitive costs of keeping one's cool. J Pers Soc Psychol Sep 79(3): 410-24.

Schinske, J., Cardenas, M., & Kaliangara, J. (2015). Uncovering scientist Stereotypes and their relationships with student race and student success in a diverse, community college setting. CBE Life Sci Educ 14(3): ar35.

Schinske, J. N., Perkins, H., Snyder, A., & Wyer, M. (2016). Scientist spotlight homework assignments that shift students' stereotypes of scientists and enhance science identity in a diverse introductory science class. CBE Life Sci Educ 15(3): ar47.

Tanner KD (2009). Learning to see inequity in science. CBE Life Sci Educ 8: 265-270.