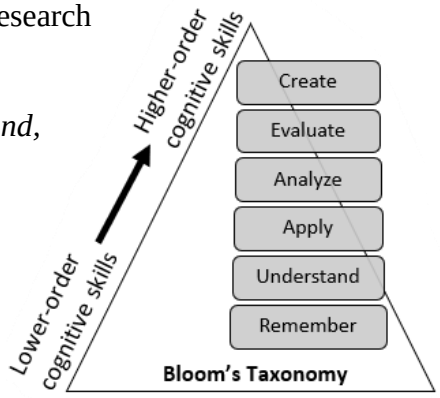
Background literature Assessment in undergraduate biology courses can consist of homework, projects, and written reports, as well as quizzes and exams. In large enrollment courses, instructors often use multiple-choice questions as an assessment method because of the ease and perceived objectivity in grading.[1] Although multiple-choice exams are useful for providing fast feedback about student performance, the multiple-choice item format has been criticized for primarily assessing low levels of cognition.[2] Biology assessments that fail to target higher-order thinking can be detrimental to the student learning process because these low-level assessments limit the development of critical reasoning and problem-solving skills, do not promote the long-term retention of course material,[3] negatively affect study habits,[4] and hinder scientific inquiry.[5]

Bloom's taxonomy is widely used in biology education research as a tool for evaluating student performance and guiding the development of instructional strategies.[6,7] Bloom's taxonomy consists of a hierarchy of cognitive skills: *remember, understand, apply, analyze, evaluate,* and *create*.[8,9] This framework can be used to categorize the cognitive levels assessed by multiple-choice and constructed-response items on biology exams.



The division of biology courses into introductory and advanced courses implies that the higher-level courses provide opportunities for students to gain a greater depth of conceptual knowledge and to practice the higher-order cognitive skills that are necessary for STEM careers. Although previous research has identified that introductory biology courses primarily assess the two lowest levels of Bloom's taxonomy,[10] there are few studies that analyze if assessments in 300- and 400-level courses target the higher-order thinking that is presumed in advanced biology courses.

The advantages and disadvantages of multiple-choice and constructed-response items are well-studied,[1] but there is little research on the extent to which the different item formats are used when assessing content knowledge and cognitive skills in introductory and upper-level biology courses. Multiple-choice items are traditionally associated with assessing the lowest levels of Bloom's taxonomy and constructed-response items are often thought to target higher-level thinking, but there has not been extensive research in biology courses to determine if there is evidence to support these stereotypes about item format.

There is a gap in the literature regarding the frequency with which multiple-choice and constructed response items are used in introductory and upper-level biology courses to assess higher-order cognitive skills. **My research will fill this gap, highlight strengths of the current methods of biology assessment, and identify the areas where assessment can be improved to better reflect the knowledge and skills that are required for success in STEM careers.**

Research Questions **1)** Is there a difference in the cognitive levels assessed in introductory and upper-level biology courses? **2)** What is the relationship between item format and cognitive level assessed on undergraduate biology exams? **3)** What decisions, processes, and methods are instructors using to design undergraduate biology exams?

Methods To answer these research questions, I will survey exams from biology instructors at a range of undergraduate institutions. Biology instructors will be recruited for participation in the research through professional networks such as the Ecological Research as Education Network and the Society for Advancement of Biology Education Research. The collected exam documents will be reviewed using a directed qualitative content analysis, a process in which each question on the exam will be categorized by a Bloom's cognitive level as well as by item type.

I will mentor undergraduate research assistants and teach them how to use Bloom's taxonomy to review exam items. I will use a Cohen's kappa analysis to determine interrater reliability for consensus of the classifications of Bloom's level and item type between the reviewers. To determine which factors predict the Bloom's level of exam items, I will run ordinal regressions with item type and course level as predictor variables and instructor as a random effect. In the analysis of Bloom's levels on individual exams, I will calculate a weighted average because items designed to assess higher-order thinking may tend to have a higher point value than items assessing lower-level cognitive skills.

I will conduct semi-structured interviews with instructors to clarify the decisions, processes and methods used to design biology exams. The interview protocol will consist of three sections: **1)** questions about possible constraints, such as large class size, that might limit the type of assessments administered in their courses, **2)** participant familiarity with Bloom's taxonomy or other frameworks for assessing cognitive skills, and **3)** goals for exam design.

This research focuses on exams because this form of assessment tends to reflect the types of knowledge and skills that students are expected to master in a course, but I acknowledge that there are assessment methods other than exams. There are some limitations to Bloom's taxonomy as a framework because of its design for broadscale application in education research. These limitations will be addressed by using the Blooming Biology Tool, which is a modification of the Bloom's framework tailored for the analysis of questions on biology topics.[7]

Intellectual Merit My experiences as a high school science teacher and as an Assessment Specialist at the Educational Testing Service provided the skillset that I will use to conduct the proposed research. Previous studies have identified that introductory biology courses primarily consist of items assessing low-level cognitive skills,[10] but there are few studies that have examined either the assessment methods in upper-level biology courses or the relationship between item type and cognitive level assessed on biology exams.

Broader Impacts One goal for this research is to strengthen the quality of the undergraduate biology education experience through identifying areas of assessment that can be improved. Students who are administered high-level items throughout their science courses are more likely to acquire deep conceptual understanding of the course material,[2] so determining where assessments can be modified to target higher levels of Bloom's taxonomy is a step in the process of promoting intellectual development in biology students. This research also addresses the disparity between the cognitive skills assessed on introductory biology exams and the cognitive skills required for solving real-world scientific problems. Although this research will be conducted primarily on assessments from American undergraduate institutions, biology exams are not unique to the United States, and the implications of this research will have international reach. A second goal of this research is to promote the advancement of biology education research, which will be accomplished through training undergraduate students in education research methodology, involving students in the process of qualitative and quantitative data analysis, and collaborating with students to present the research at science conferences.

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(1) Stanger-Hall, K. F. *CBE Life Sci. Educ.* **2012**, *11*(3), 294-306. **(2)** Martinez, M .E. *Educational Psychologist*. **1999**, *34*(4), 207-218. **(3)** Jensen, J. L. *et al. Educ. Psychol. Rev.* **2014**, *26*(2), 307-329. **(4)** Entwistle, A.; Entwistle, N. **1992**, *2*(1), 1-22. **(5)** Momsen, J. *et al. CBE Life Sci. Educ.***2013,** *12*(2), 239-249. **(6)** Bissell, A. N.; Lemons, P. P. *BioScience*. **2006**, *56*(1), 66-72. **(7)** Crowe, A. *et al. CBE Life Sci. Educ.***2008**, *7*(4), 368-381. **(8)** Bloom, B. S. *et al.* McKay: New York, NY, 1964. **(9)** Anderson, L. W.; Krathwohl, D. R. Allyn & Bacon: Boston, 2001. **(10)** Momsen, J. *et al. CBE Life Sci. Educ.* **2010**, *9*(4), 435-440.