Journal of Mammalogy, XX(X):1–12, 2023
https://doi.org/10.1093/jmammal/gyac121

Teaching Mammalogy in the 21st century: advances in undergraduate education

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In the past 30 years, leaders in undergraduate education have called for transformations in science pedagogy to reflect the process of science as well as to develop professional skills, apply new and emerging technologies, and to provide more hands-on experience. These recommendations suggest teaching strategies that incorporate active learning methods that consistently increase learning, conceptual understanding, integration of subject knowledge with skill development, retention of undergraduate students in science, technology, engineering, and mathematics (STEM) majors, and inclusivity. To gain insight into current practices and pedagogy we surveyed members of the American Society of Mammalogists in 2021. The survey consisted of both fixed-response questions (e.g., multiple-choice or Likert-scale) and open-ended questions, each of which asked instructors about the structure and content of a Mammalogy or field Mammalogy course. In these courses, we found that lecturing was still a primary tool for presenting course content or information ($\bar{x}$= 65% of the time); nonetheless, most instructors reported incorporating other teaching strategies ranging from pausing lectures for students to ask questions to incorporating active learning methods, such as debates or case studies. Most instructors reported incorporating skill development and inclusive teaching practices, and 64% reported that they perceived a need to change or update their Mammalogy courses or their teaching approaches. Overall, our results indicate that Mammalogy instructors have a strong interest in training students to share their appreciation for mammals and are generally engaged in efforts to increase the effectiveness of their teaching through the incorporation of more student-centered approaches to teaching and learning.

Key words: active learning, inclusive teaching, Mammalogy, pedagogy

For more than 30 years, professional organizations such as the American Association for the Advancement of Science (1989), the National Science Foundation (AAAS 2009), and the Association for Public Land Grant Institutions have called for improvements in how we teach undergraduate students and for incorporating more professional skill development and training within college courses (Crawford et al. 2011). Much of the emphasis on change stems from concerns surrounding the loss of students from science, technology, engineering, and mathematics (STEM) education early in their undergraduate careers, with particular concern about the loss of students from underrepresented groups (AAAS 2011). Employers also have raised concerns that students are not graduating with the skills necessary to be successful in their careers. These two concerns are not mutually exclusive: developing skills leads to gains in self-efficacy, the belief in one's ability to perform a behavior (Bandura 1997), and subsequent persistence in STEM majors, which may help retain students early in their programs and increase diversity in these fields (Koenig et al. 2012; Graham et al. 2013).

Arguably, the most recommended change to address these concerns is to move away from traditional lectures and toward active learning formats, or from instructor-centered to student-centered teaching. Nevertheless, despite decades of calls for change, traditional lectures continue to be the most common teaching strategy in STEM courses in the United States (Stains et al. 2018). This fact is alarming, given the growing body of literature indicating that traditional lecturing is less effective and often detrimental at helping students achieve learning goals (and sometimes even harmful) and because traditional lecturing does not teach the critical thinking skills required for successful STEM careers. For example, students in courses taught using traditional lecturing methods may retain only 10–20% of the lecture content (Fischer 2011; Murre and Dros 2015), whereas students remember 80% in active learning classrooms with repeated interaction with information (Handelsman et al. 2004; Murre and Dros 2015). Teaching using active learning methods requires more time, and content coverage can be lower than in a lecture-based classroom. Instructors can focus this teaching on key concepts using backwards design (Wiggins and McTighe 2005) to ensure that instructional activities meet the course learning objectives. Furthermore, overall student performance (e.g., meeting course objectives and course grades) is also higher in active learning courses compared to traditional lecture courses (Knight and Wood 2005; Freeman et al. 2014). Traditional lecturing results in very little interaction between instructors and students, which has been identified as a cause of continued low diversity in STEM (Harris et al. 2020b). Similarly, lower quality of teaching in STEM courses has been one of the top reasons cited by undergraduate students leaving STEM majors for decades (Seymour and Hewitt 1997; Hunter 2019). Thus, active learning methods and student-centered classrooms may also be the solution to increasing the number and diversity of students who graduate with STEM degrees (Freeman et al. 2014).

Active learning is grounded in the foundational education theory of constructivism (Dewey 1916). When students are provided with opportunities to work through information actively, to ask and to answer questions, to link new information to their existing knowledge, to receive feedback on learning, and to integrate skills with content knowledge, they learn and retain more new information and concepts. Combined, these activities lead to long-term memory development and greater learning gains. Similarly, scaffolding of knowledge (i.e., revisiting content across the curriculum) further advances learning by allowing learners to add new information to their existing knowledge frameworks. The efficacy of this learning structure is based in neurobiology: repetition, active engagement, and student involvement in learning combined with the use of all five senses lead to the changes in brain structure necessary for long-term memory development and learning (Friedlander et al. 2011). Such deep learning is rarely, if ever, achieved during a traditional lecture course because of the lack of opportunities for students to work with information (Chin and Brown 2000).

Use of inclusive teaching practices is another means for increasing student success in meeting learning objectives and retention in undergraduate STEM courses. Inclusive practices are those that address the learning and educational needs of all students, regardless of their differences and abilities (Dewsbury and Brame 2019). These methods also provide all learners with equal opportunities for learning experiences that support their success (Lawrie et al. 2017). Academic culture historically has focused on individual work and tasks instead of on process, with information siloed into course topics, and with inflexible deadlines and schedules. These practices reward students who are more affluent, who do not need to work during their time at universities, who do not have other responsibilities outside of their courses, and those from families with a legacy of attending college and the associated role models and support systems (Ibarra 2001; Weissmann et al. 2019). Rather, students who identify as female, Indigenous, African American, Asian, Hispanic, and first generation tend to perform best in settings that incorporate group learning activities, less formal settings with greater personal interactions, flexible deadlines, and an emphasis on the process rather than the task (Ibarra 2001; Chavez and Longerbeam 2016; Gillis and Krull 2020; Moore 2020). Welcoming classroom climates, which are created when instructors use a variety of approaches to support the learning preferences of students, can have many benefits, including instructors connecting with their students over the content and developing metacognitive skills in students. Approaches such as decreasing or down-playing high-stakes evaluations (like a single course exam), providing flexibility with deadlines for students that may have responsibilities outside of their courses, and incorporating skill development are all strategies for increasing inclusivity in courses (Freeman et al. 2007; Sathy and Hogan 2019; Moore 2020). These inclusive teaching practices create more equitable learning environments and benefit all students.

Undergraduate courses can also be an opportunity to teach beyond content knowledge; courses can prepare students for their future careers by incorporating skill development and providing opportunities to develop professional identities (Yahnke et al. 2023). One important pathway for students to build self-efficacy and to gain professional skills is through an extracurricular undergraduate research experience (Munroe 2023). Traditional research opportunities are often limited to a subset of students who do not have other time commitments (e.g., work or caregiving responsibilities) and who are able to volunteer (i.e., can afford to work without pay). This initial inequality can lead to a self-perpetuating cycle of exclusion for low-income, nontraditional, or marginalized students because privileged students who can afford to volunteer in a research experience will continue to secure more opportunities because of their experience (Bangera and Brownell 2014). Extracurricular opportunities also tend to be the primary venues for students to receive career mentoring, learn about the process of applying for graduate school, and evaluate their career decisions to determine if they will actually enjoy their future jobs (Seymour et al. 2004); thus, differential access to these opportunities also perpetuates initial inequalities in experiences. Clearly, research opportunities benefit all students, and they need to be made more accessible, perhaps by being integrated into courses so that all students have access to the experience, not just a select few.

Given the clear need for continued change in undergraduate education to support our students and a diverse STEM workforce, including in the field of mammalogy, we investigated the current teaching practices used in Mammalogy courses. Our goal was to develop an understanding of the current state of mammalogy teaching and to identify ways that as a professional society, we can serve our students and our community better.

Materials and Methods

Prior to and during the virtual 2021 American Society of Mammalogists Annual Meeting, we surveyed ASM members teaching Mammalogy courses to gain insight into the current practices and pedagogy specifically used for Mammalogy courses (see Supplementary Data SD1). We recruited participants for 6 weeks via the Mammal-L listserv and by sharing the survey link with conference attendees in educational symposia and workshops. This survey was conducted in Qualtrics, was both anonymous and voluntary, and was reviewed and found to be exempt by the Purdue University Institutional Review Board (Protocol # 2021-893).

The survey consisted of 33 fixed-response questions (e.g., multiple-choice or Likert-scale) and 11 free-response questions, each of which asked instructors about the structure and content of a Mammalogy or field Mammalogy course. Some of the questions allowed instructors to select multiple options, including those describing demographic information about themselves or their academic institution. The survey was developed using questions from the Teaching Practices Inventory (https://cwsei.ubc.ca/resources/tools/tpi), with additional specific questions focused on mammalogical content. Instructors were asked to complete the survey about their courses in a typical nonpandemic year, which might include modifications that they planned to continue postpandemic, but not temporary measures from the emergency pivot to online courses during the COVID-19 pandemic (reviewed by Beckmann 2023).

We calculated descriptive statistics and frequency of responses for each of the fixed-response questions. For each of the free-response questions, we identified major themes in the responses qualitatively. We also performed exploratory chi-square analyses to identify whether certain teaching practices were associated with instructor demographics, training, or teaching experience; however, such analyses were limited due to low sample sizes and the fact that some participants skipped questions.

Results

Demographics and training.—A total of 41 individuals responded to the survey. Of those individuals, 39% were full professors, 24% were assistant professors, 18% were associate professors, 10% were lecturers, 3% were graduate students, 3% were emeritus professors, and 3% were adjunct professors. A slight majority of respondents identified as female (54%) and most reported their primary area of training as ecology (41%) with others reporting evolution (19%), wildlife (13%), physiology (11%), taxonomy (5%), and other (11%; molecular and disease ecology, ecology and physiology, or conservation biology). Nearly half of respondents (48%) now teach Mammalogy at a Ph.D. granting institution, 29% teach at a primarily undergraduate institution, 17% at a Master's granting institution, and 15% are at small liberal arts colleges, with some respondents teaching at or selecting multiple institution types. Most participants teach in a biology department (69%) while others are in zoology (15%), ecology and evolutionary biology (13%), forestry and natural resources (10%), environmental sciences (10%), wildlife and fisheries (8%), and other (2%) departments, with some respondents describing their department as a combination of disciplines.

Most of the Mammalogy courses for which respondents answered the survey questions were upper-division courses for juniors and above (48%) or seniors (77%). The typical course size was relatively small, with 30 or fewer students (66%), and most courses included a lab (94%). Nearly all Mammalogy courses formed part of the curriculum for a major (82%) rather than as an elective, and 96% of the courses required at least one biology course as a prerequisite. Instructors reported that most students in their Mammalogy courses were hoping to pursue wildlife careers with free-ranging populations (65%) or with captive populations (e.g., zoos or wildlife rehabilitation; 27%), and 38% reported that their students were interested in pursuing graduate school opportunities in STEM.

When asked about training or professional development for teaching, 27% reported no formal or informal training or professional development for teaching. The most common responses for those who had received training were a short workshop as a teaching assistant (41%), workshops and trainings outside their institutions (35%), weekend or multiday workshops at their institution (30%), a mentored teaching experience (22%), or a short workshop when they began as a new faculty member or instructor (22%). 'Other' responses (35%) included courses during graduate programs (n = 2), teaching groups (n = 1), workshops series (n = 2), work as an educational consultant (n = 1), postdoctoral training in education (n = 2), and conducting research in the science of teaching and learning (n = 1). Workshops at conferences, graduate teaching certificate programs at universities, and national programs were common responses when asked a free-response question about teaching programs that respondents attended.

Structure of Mammalogy courses.—When teaching Mammalogy, only 34% of responding instructors required a textbook, whereas 70% required students to read scientific papers and 14% required 'other' resources like popular literature. Most courses required students to take a field trip to a wild or natural area (56%) or to a museum (51%), but field trips to zoos or aquariums, trips to urban areas, or overnight trips were typically not included or were optional. The course grading schemes indicated that Mammalogy instructors were incorporating multiple types of evaluation in the courses. Except for in-class or in-lab quizzes, no single category of assignment accounted for the majority of the evaluation (Fig. 1); however, for many respondents, quizzes were not part of the course evaluation. Midterm exams, papers or projects, in-class activities, a final exam, and 'other assessment methods' were evaluation methods that, when used, often comprised 25–49% of the course grade. When instructors used midterm exams, 52% of respondents included at least two exams. When assessing students in lab (if the course involved a lab), the most commonly reported assessments were regular lab quizzes (69%) or a lab final exam (66%). Other lab assessments included independent lab projects (37%), group projects (31%), lab hand-outs (28%), lab reports (28%), and other assessments (26%; e.g., written responses in field notebooks or journals, multiple lab exams [practical or written], study skin preparation, or data collection).

A total of 30 instructors shared the learning objectives of their courses on the survey but learning objectives may not completely reflect course content. Mammal ecology and diversity were broad topics included in all the learning objectives, whereas skill development was reported less often (Table 1). Of these 30 responses, 23 (77%) specifically acknowledged that identification of mammals was one of their learning objectives. Use or development of communication skills through writing assignments or synthesis of primary literature was included in 40% of the courses, whereas skill development related to methods or techniques used in mammalogical research (e.g., trapping, marking, field observations) was included in only 25%. Quantitative reasoning or working with or interpreting data were learning objectives for 18% of courses. Only 8% of respondents stated museum skills like skull or study skin preparation as a course learning objective, and only two respondents (7%) reported career development or learning about mammalogy careers as a learning objective.

Access to collections.—All respondents to the question about collections ($n = 38$) reported having a teaching collection; however, 21% reported that their collection was very small and not sufficient for their teaching needs. Most reported that their collection was reasonably representative of regional diversity (55%), and some reported collections with a very good representation of mammals beyond the regional level (21%). One respondent selected 'other' and reported that their collection was small but was sufficient for their teaching needs, even if it was not reasonably representative of regional diversity overall.

Instructional format.—In these Mammalogy courses, lecturing was still a primary tool for presenting course content or information ($\bar{x}$= 65% of the time, max = 95%, min = 10%); nonetheless, many instructors reported incorporating other teaching strategies (Fig. 2). There was no significant difference

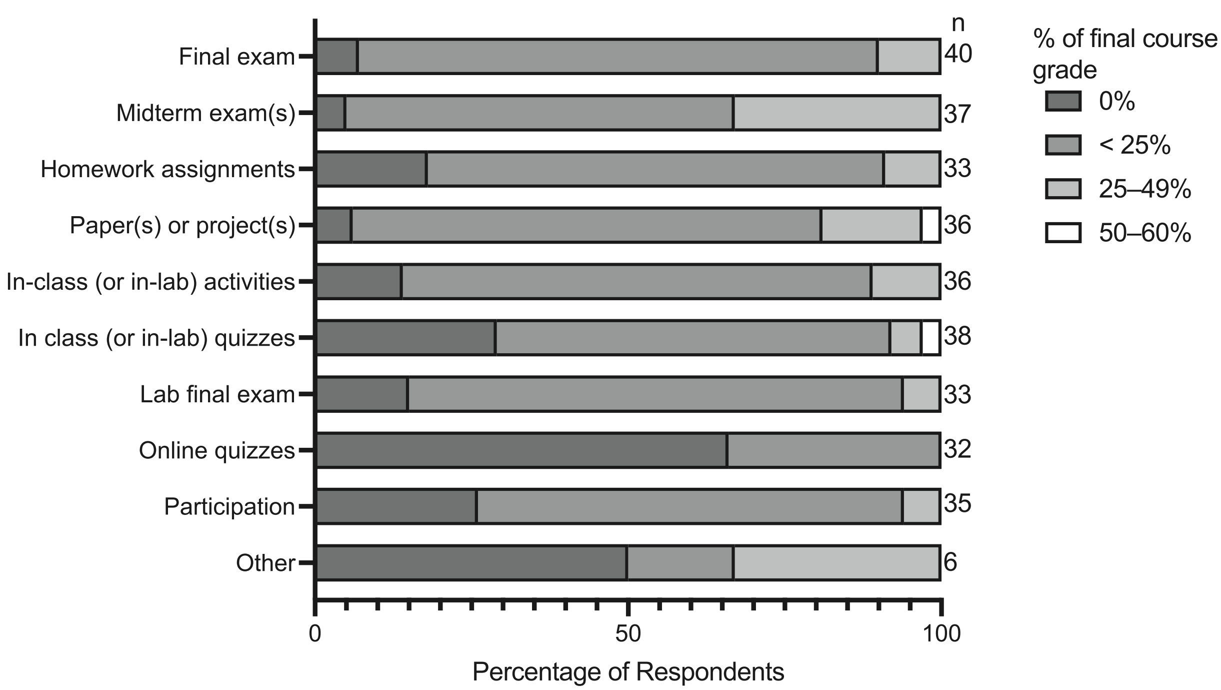

Fig. 1.—Approximate breakdown (in percent) of course grades based on different evaluation methods for instructors teaching Mammalogy in 2021. The sample size for each evaluation method is also provided; not every instructor used each method, which led to differences in sample sizes for the different evaluation methods.

Table 1.—Summary of the major themes identified from the learning objectives of a sample of 23 Mammalogy course syllabi. Examples of learning objectives associated with each theme are included.

Overarching theme	Common elements of theme	Example learning objective(s)
Core content in mammalogy	Characteristics of mammals	Describe the unique morphological, anatomical, and physiological adaptations of mammals that constitute their strategies for success compared to other groups of animals
	Classification and identification	Identify groups of mammals and the unique features that define each group *Note: Taxonomic "depth" requirements (i.e., order/family/genus/species) often and appropriately differ by local/regional/global taxa. We recommend specifying to what level students should be able to recognize/identify species from different geographic regions.* Use a dichotomous key to identify an unknown mammal specimen, skin, skull, or photo
	Application of mammalogy to other fields of study	Describe important behaviors, conservation status, and economic importance of mammals in this region and globally Use case studies of mammals to explore classic and contemporary issues in animal behavior, biogeography, conservation, ecology, and evolution
	Structure and function	Identify how the anatomy, physiology, and behavior of mammals are adapted to specific environments, geographies, and ecological niches
	Evolution, phylogeny, trees	Identify and interpret evolutionary relationships and patterns of character evolution in mammals and nonmammal synapsids Describe the geological, environmental, and ecological factors that contributed to the radiation of mammals
Practical skills specific to mammalogy	Collections methodologies	Prepare a museum skin or skull Communicate the importance of preserved specimens and museum collections in the field of mammalogy
	Field methodologies	Understand the role of various field techniques in the study of mammals, explain how these techniques lead to scientific knowledge, and use field techniques to measure mammal diversity, distribution, behavior, or population size
General skills in the sciences	Science process skills	Formulate hypotheses, design field or laboratory studies of mammal biology, manage and analyze data, and interpret scientific graphs and data
	Literature research skills	Find, read, analyze, interpret, and synthesize primary literature focused on mammals and use ideas from the literature to articulate opinions and propose new research questions
	Communication skills	Communicate your understanding of scientific processes and results via diverse media (e.g., in writing, oral presentations, class discussions, audiovisual representations, or creative compositions)
	Career skills	Develop professional skills such as oral and written communication, teamwork, and problem-solving skills, that will support success in future careers as a mammalogist or in graduate school.

between instructors that had received formal teaching training and those that had not in terms of their reported use of lecturing ($t_{0.05(2)13} = 0.405$, $P = 0.69$). All instructors reported pausing in a typical class period 1–2 times to allow students time to ask questions. Most instructors break up their lectures by incorporating small group discussion or problem-solving activities in a typical class period (65%), showing demonstration simulations or video clips (95%); or asking questions with a pause for student-to-student discussion (100%). In contrast, use of other active learning activities during the course, like concept maps, debates, presentations, short essays, and case studies, was infrequently included in most courses (Fig. 2).

Regarding other learning activities, 54% of respondents reported using graded homework or problem sets assigned at intervals of 2 weeks or less, and a course paper or project that would require >2 weeks of time was included in 89% of courses. Explicit group assignments were used by 49% of instructors, whereas 68% encouraged and facilitated collaborative work on assignments. Feedback to students on assignments was most often provided by allowing students to review graded assignments (92%) or to review the assignment answer key or grading rubric (59%). Feedback on exams was provided by allowing students to review graded exams (84%) or the answer key (49%). Most instructors explicitly encouraged students to meet individually with them (89%).

The majority of Mammalogy lecture and lab instructors reported including research and communication skills in their courses. Developing questions and hypotheses and approaches for data collection were the most common pathways for incorporating these skills (65% and 57%, respectively). Instructors largely required students present results either orally (68%) or in written format (62%), whereas a few had students present results as an art project (14%). Many instructors provided students with autonomy to select questions to consider (71%) and to work in groups on assignments (73%).

Regarding learning activities, most instructors had students examine mammal specimens at least three times during the course (67%) or identify mammals based on specimens (84%; Fig. 3). Most also provided students with opportunities to observe live mammals at least once (79%), live trap mammals at least once (68%), or handle live mammals (52%). Other mammal-related skill-based activities like camera trapping, radiotelemetry, or preparation of study skins were included less frequently (Fig. 3). Use of illustration (i.e., sketching or drawing) was encouraged by most respondents (61%), required by a few (8%), and not included by 31% of instructors. When asked about the use of other specific learning tools, the Squirrel-Net Course-based Undergraduate Research Experience (CURE) modules (Dizney et al. 2020) were used by 39%, followed by writing or revising Animal Diversity Web or Wikipedia accounts (35%), activities from the Ryan (2019) Mammal Techniques Manual (22%), data-focused activities from Quaardvark (22%), SnapshotUSA (Cove et al. 2021; 17%), other CUREs (9%), or conducting a Biodiversity Literacy in Undergraduate Education activity (4%). Respondents also reported using "other" (30%) activities, including original inquiry-based exercises, modified HHMI Biointeractive (biointerative.org) activities, having students create their own 'Life of Mammals'-style videos, or develop their own research questions, specimen preparations, or presentations.

Inclusive teaching.—Incorporation of diversity, equity, and inclusion (DEI) or intercultural skill development in Mammalogy courses was relatively low (Fig. 4); nevertheless, many instructors who were not yet incorporating these topics or skills noted that they are considering adding them. For example, 81% of the survey respondents reported that they were now or were considering highlighting diverse voices and authors for studies featured in class. Similarly, 77% of the instructors noted that they either were or were considering using inclusive

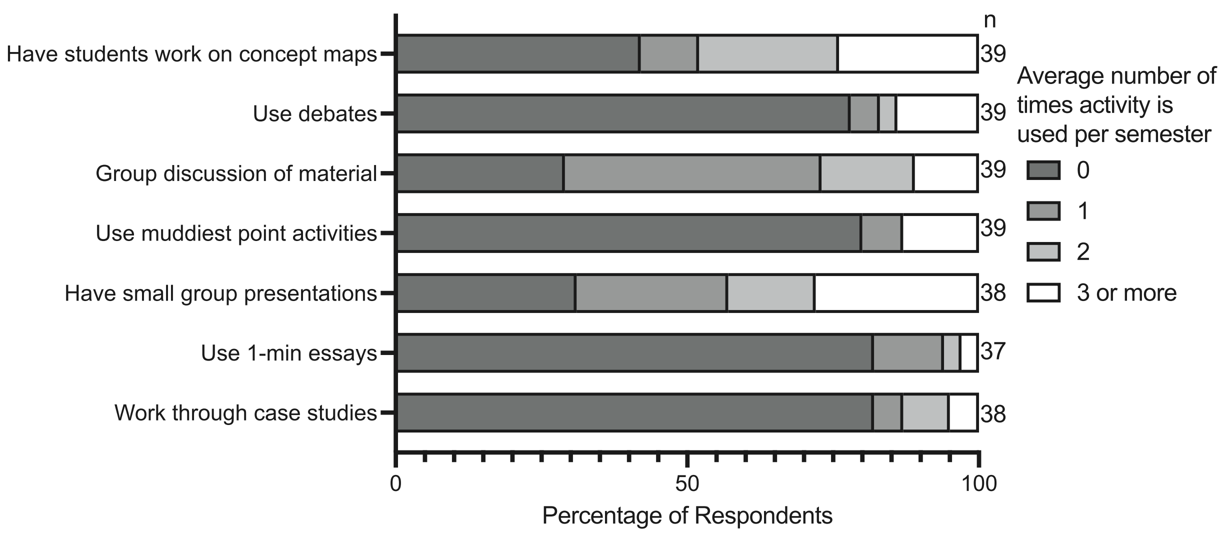

Fig. 2.—The percentage of respondents in 2021 that used the following active learning methods and the average number of times each activity was used during a typical course.

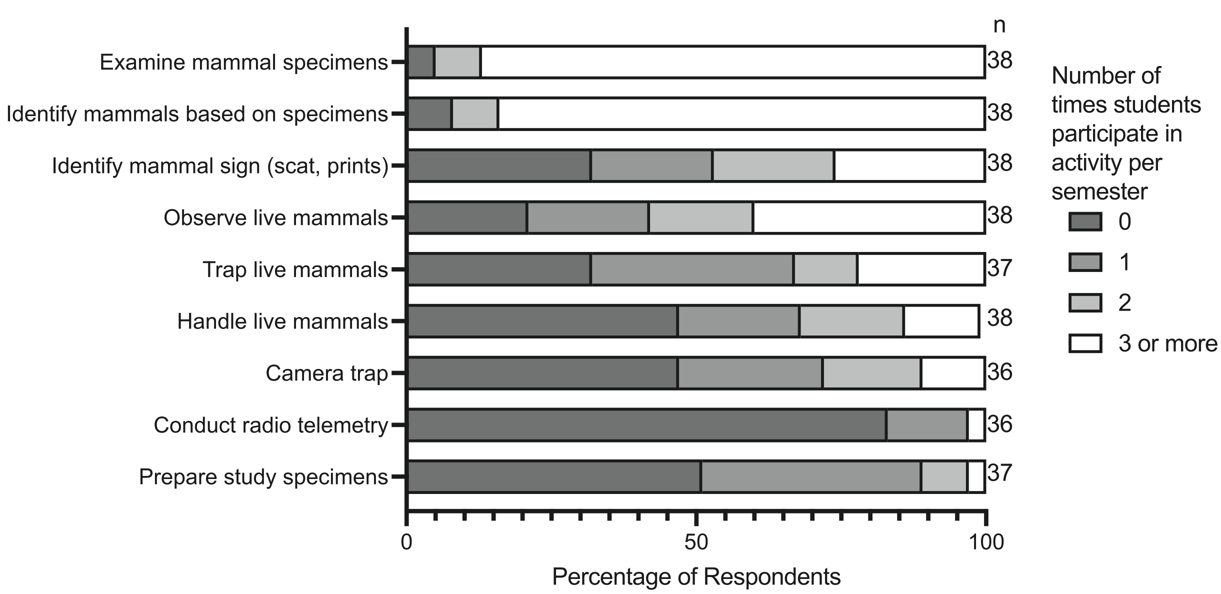

Fig. 3.—Frequency with which students were expected to participate in different activities during a typical course (i.e., before or beyond pandemic-related disruptions).

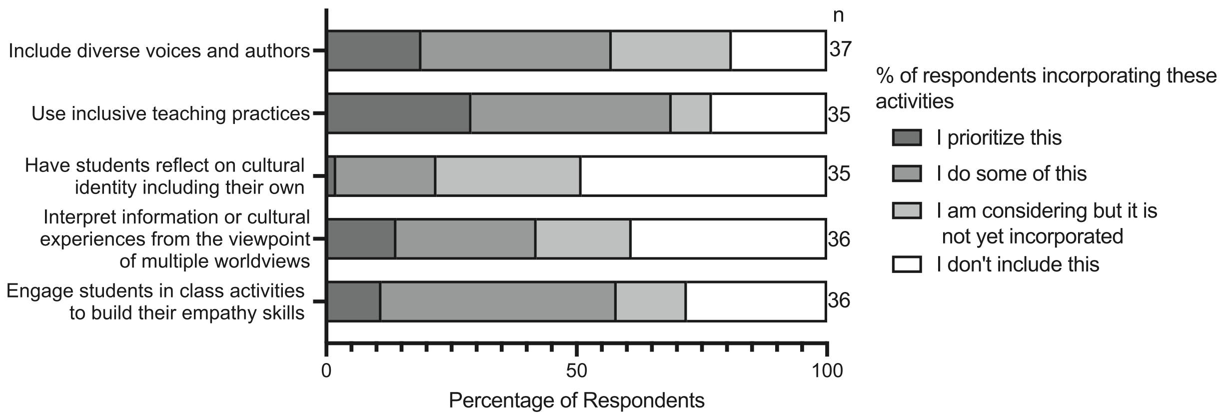

Fig. 4.—The percentage of responding instructors that incorporated diversity, equity, and inclusion (DEI) or intercultural competency skill development into their Mammalogy course.

teaching practices. We found no association between the number of the DEI activities an instructor reported prioritizing or somewhat using in their course and instructor gender (χ^2_5 = 4.778, P = 0.837) or the instructor having received any formal teaching training (χ^2_5 = 2.090, P = 0.444). We were unable to perform any additional exploratory contingency analyses due to low sample sizes and missing data for either demographics or course survey questions.

Updating teaching materials.—When asked if instructors perceived a need to change or update either their Mammalogy courses or the teaching approaches they used in their classes, 64% responded yes and they are actively working on it, 17% responded yes but they do not have time, and 19% responded no. Similarly, when asked if they made any changes during the COVID-19 pandemic that they anticipated retaining, most responses to this question (79%) reported they plan to retain at least one change they made for future courses. In terms of the barriers to implementing change that were identified by these instructors, insufficient time was the most common response, but Institutional Animal Care and Use Committee approval, other permitting requirements, and funding were also reported as barriers to implementing change.

Discussion

Overall, responses to our survey indicated that Mammalogy instructors are passionate about their course topic and sharing their knowledge with students, and that they have a strong interest in training students to appreciate mammals and the field of mammalogy. The majority of respondents indicated they are professors teaching at institutions with a graduate program and had received little to no formal teaching training, which is common for academic faculty across most STEM disciplines and institutions (Handelsman et al. 2004; Brownell and Tanner 2017). Notably, the responses to the survey question about training made it clear that instructors understand the need for training in pedagogy and are seeking this professional development on their own, even if such training is not required by their institution. To this end, we have provided some suggestions and recommendations for making Mammalogy courses student-centered (Box 1; see also Patrick et al. 2023). These suggestions follow directly from the results of our survey, include ideas submitted by respondents, and are specifically curated to overcome barriers to change identified in our survey.

Responses indicated that even though only 2 of the 30 sets of learning objectives shared in the survey explicitly included career development or discussion of careers, many Mammalogy instructors are using learning activities that develop and build skills associated with future career success including: mammal identification, communication, data analysis, collaboration, and research skills. We suggest that instructors could emphasize the career-related benefits of activities that develop these skills, so that students may anticipate and manage expectations for their future careers better. In so doing, students might also recognize that they are receiving professional development experiences like those in extracurricular opportunities. Linking course material to future career success is especially important given that nearly all courses described in the survey responses were for junior- or senior-level undergraduate students, who will be entering the workforce within the next few years. Furthermore, 38% of instructors reported that their students are interested in pursuing graduate school, where these professional skills will not only be foundational to their admission and success but may also determine their satisfaction with the graduate school experience.

Active learning in Mammalogy classrooms.—Our survey also reveals that one of the most effective teaching methods for preparing students to be successful in future mammalogy or ecology careers, active learning, is currently underused in Mammalogy courses. According to instructor perceptions, the majority of students in the Mammalogy courses plan to pursue STEM-related careers where critical thinking is valued and expected. Yet, Mammalogy instructors report using traditional lecturing 65% of the time, which evidence suggests is not the most effective strategy for preparing students for these careers. This statistic may also be an underestimate of time spent lecturing across all Mammalogy courses, because our survey was likely biased toward instructors who are interested in improving their teaching practices, whereas those who rely exclusively on traditional lecture methods may have been less likely to respond to the survey.

Box 1.—Recommendations for Instructors: Recentering Mammalogy education and focusing the Mammalogy courses on the students rather than on the instructor.

- Create a classroom climate of inclusion by providing students with opportunities to get to know each other. Consider first introducing yourself to your students by sharing your name, pronouns, and some background on your pathway to your current career. You could also share the story of your first, middle, or last name as a way for students to get to know you as a person beyond your career. For example, sharing if your name is a family name, how your parents chose your first name, your preference in the version of your name you would like others to use, or the history of your name. Provide students with an opportunity to share as much similar information with you as they want or feel comfortable sharing. This can be achieved with a worksheet, notecards, Google slides or forms, or most any format. Such an invitation is also an opportunity to ask students about topics that interest them so that you can weave those topics into the course to help them connect with the content.
- Emphasize the career-related benefits of activities that develop professional skills, such as communication, data analysis, and collaboration, which allow students to understand better connections between class activities and assignments and careers. This linkage will help students recognize the relevance of the course to their professional development and future careers in STEM.
- Prioritize personal interactions with students, even if these occur simply by walking around a large classroom during a group activity and asking students about their thought processes. Such personal interactions are important in retention and inclusivity in STEM.
- When possible, convert lecture activities to active learning activities by allowing students to puzzle through data, morphological characters, or phylogenies themselves (or in small groups), rather than simply providing the answer. Specific examples of converting course activities from traditional lectures to active learning methods are reviewed by Patrick et al. (2023).
- Start by modifying or updating a few activities or class periods each year, rather than trying to convert an entire course at once. Over time, this effort can lead to a significant difference in the student experience, without exhausting instructor time or energy.
- Do not feel the need to create original activities for every change you make in a course. Rather, take advantage of shared, free resources online, such as the National Center for Case Studies Teaching in Science (https://www.nsta.org/case-studies), CourseSource (qubeshub.org), or networked CUREs with readily available modules, like Squirrel-Net (squirrel-net.org) and BCEENET (Biological Collections in Ecology and Evolution Network; bceenet.org).
- Take advantage of teaching-related workshops and symposia at professional conferences, which allow you to develop and to hone teaching skills while attending a scientific meeting.
- Communicate to students the reasons why active learning methods are used in a course and the benefits of this format. Articulate expectations for participation clearly and be transparent about the process. These techniques can help improve students' attitudes about active learning methods if they communicate a preference for passive lecturing.
- Release yourself from strict expectations of content coverage and instead focus on development of research skills to help students learn new information on their own. You can then ask students to apply these science process skills to a new content area in an assessment like an exam, homework, presentation, etc.
- Consider incorporating a variety of assessments or evaluations, beyond a few high-stakes exams, to allow all students an opportunity to be successful. Similarly, consider the cost when selecting educational materials (e.g., textbooks, readings from the literature, etc.), and consider providing copies for students to review or to check out briefly at the library.
- Consider incorporating intercultural content, such as an activity or discussion on traditional ecological knowledge, culturally sensitive mammal research and conservation, and the cultural importance or relationships of indigenous people with certain mammals (e.g., see resources by Kimmerer 2002; Ostertag et al. 2018; Ramos 2018; Waller and Reo 2018; Ahmad et al. 2021).
- Try to highlight papers by a diversity of authors and introduce these authors to students with a photo and background information. A variety of repositories that highlight publications by diverse authors exist, such as projectbiodiversify.org.

Fortunately, mammalogy and ecology are disciplines that lend themselves well to incorporating active learning methods in the classroom. For example, rather than pointing out the morphological differences among a group of closely related mammals while students passively listen, instructors could provide students with images or specimens, then have students identify those characters in small groups, and finally review the answers as a group. Such an activity leads to greater learning gains, reinforces observational and communication skills, and affords instructors the opportunity to move around the classroom and interact personally with students. These personal interactions, which are possible in this way even in a large lecture-format classroom, aid in retention, and build a sense of inclusion, especially for students from marginalized groups (Ballen et al. 2017; Dewsbury and Brame 2019; Harris et al. 2020a; Theobald et al. 2020).

Active learning methods can also incorporate activities that reflect better the expectations for STEM careers and professionals. Most aspects of a mammalogy-related job require critical thinking, problem-solving, communication, and working in teams. Incorporating these skills in Mammalogy courses, rather than relying on lectures, will help to prepare students to become lifelong learners who have the skills to take responsibility for their own knowledge.

Despite the clear benefits for students of teaching using active learning methods, many barriers exist, causing instructors to continue using instructor-centered lecturing. These barriers include lack of time and resources for converting traditional lecturing to active learning methods, resistance from students, concerns about teaching evaluations, and concerns about a reduction in course content (Michael 2007; Miller and Metz 2014; Brownell and Tanner 2017). Time is a prized and limited resource for all instructors, and it has been even more limited with the added requirements and challenges of teaching during a pandemic. Indeed, we recognize that converting an entire course from a traditional lecture to an active learning format is an enormous task. Nevertheless, modifying and updating a few class periods or topics annually can lead to a significant difference in student learning and retention, and over time, chipping away at traditional lectures can lead to a fully active learning-based course.

Many active learning methods require very little time to prepare or to incorporate into existing lesson plans, such as think-pair-share. In this activity, students first reflect on a question, then each turns to a student sitting adjacent to discuss their thoughts, and finally, all share their answers with the whole class. In addition, many instructors now share activities, ideas, and materials, such that diverse resources are readily available. Many other sources and activities are reviewed by Patrick et al. (2023), including online repositories of case studies like the National Center for Case Studies Teaching in Science, CourseSource (qubeshub.org), or networked CUREs with plug-and-play modules like Squirrel-Net (squirrel-net.org; Connors et al. 2020), and BCEENET (Biological Collections in Ecology and Evolution Network; bceenet.org). These resources are free, ready to be implemented in new classes, and some offer to provide equipment or supplies to instructors. Many published resources also include teaching notes and answer keys, which can substantially reduce instructor preparation time. Increasingly, professional conferences (including those of the American Society of Mammalogists) offer teaching-focused workshops, so instructors can develop or hone their teaching skills while attending annual meetings.

Another perceived challenge with implementing active learning methods in the classroom can be the preference of students for traditional lectures and the related risk to instructors when students then evaluate their teaching and the course (Smith and Cardaciotto 2011). Furthermore, some students may cling to the misconception that they learn better during lectures, but in reality, this perception is rarely supported by assessment of their performance or course grades. Numerous studies (e.g., Freeman et al. 2014) have shown that students learn more information and perform better on exams in active learning settings where they engage with information and with each other, compared to a traditional lecture setting (Hake 1998; Prince 2004; Knight and Wood 2005; Jensen et al. 2015; Deslauriers et al. 2019). Active learning methods require students to be fully engaged in class and to work to develop their own knowledge and skills; it does not reward sitting and listening passively. Many students are unaccustomed to being held responsible for their own learning and are unaware of the benefits, so they may be resistant, initially struggle with the format, or experience a temporary decline in their self-confidence (Woods 1994).

Student complaints associated with the initial discomfort of experiencing a new learning format are often the reason why instructors revert to passive lecturing after trying active learning methods (Henderson et al. 2012). Unfortunately, student attitudes toward an instructor and course are reflected in course evaluations, which are still used in promotion and tenure decisions, selection of teaching award recipients, and other teaching evaluations despite decades of evidence of bias in this evaluation (Boring et al. 2016; Hornstein 2017; Fan et al. 2019). Thus, evaluation scores are still powerful influences as to whether an instructor shifts to active learning methods. Communicating to students the reasons why active learning methods are used in a course and the benefits of this teaching format, as well as providing transparency about the process and expectations for participation can improve the attitudes of students, help them to manage their expectations, and help them to appreciate the benefits that they gain from a course (Tharayil et al. 2018).

While it is true that less content likely is covered in a course using active learning methods than traditional lecturing, we argue that the trade-off for higher student achievement, improved attitudes, and career development is an investment in student success (Sundberg et al. 1994; Hunter 2019; Yahnke et al. 2023). If students retain less than 20% of content from lecture courses (Fischer 2011), content-intensive instruction can counterintuitively harm student comprehension and attitudes about science (Sundberg et al. 1994). Likewise, because content overload is a reason undergraduate students leave STEM majors (Hunter 2019), the trade-off for a "less is more" approach seems beneficial. Similarly, few STEM careers require professionals to recall every fact they learned in their undergraduate education; rather, professionals must be able to find such information quickly and efficiently and, more importantly, draw conclusions, apply, or act upon that knowledge. Thus, we suggest that teaching students these important processes (i.e., through active learning) may actually prepare them *better* for professional careers (Yahnke et al. 2023), even if it comes at the cost of content coverage. Furthermore, using a backwards design approach to course development and planning (Wiggins and McTighe 2005) will ensure that the material covered in active learning activities addresses the most important course objectives.

Although many instructors find content reduction uncomfortable (e.g., because it contradicts the way that they themselves were trained), several techniques can help instructors evaluate whether students are still introduced to all of the important content areas. One such approach is to consider moving some content areas to assessments (e.g., data analysis questions on exams, presentations over the primary literature, writing assignments). For example, if the shift to using active learning methods causes an instructor to cut a certain content area, concepts from that content area can appear as a question on an assessment in which students are asked to interpret a figure and draw conclusions from that figure. In this way, students learn about that content area by working through the concepts themselves, thereby applying the science process skills that they were taught in the course. This approach also reflects better the expectations of professionals in STEM careers (i.e., the ability to learn independently and to draw conclusions from data). Thus, while we validate instructor concerns regarding the move to active learning approaches, we also contend that the benefits to students outweigh the costs.

Inclusive teaching in Mammalogy.—While we acknowledge that there is likely a bias in the respondents for our survey, with those that participated most likely engaged in activities to improve their teaching methods, a promising outcome is the high interest and intent from instructors to modify their courses in ways to benefit all students and to incorporate more DEI content. Additionally, survey results indicate that most of the respondents are already using some inclusive teaching practices, such as multiple forms of assessment or evaluation. Instructors are also building activities into their courses, like examining and identifying specimens, traveling to visit natural areas to observe wild mammals, and visiting museums and zoos. Indeed, examining and identifying specimens is an easy way to incorporate active learning methods and could be made even more active and inclusive by following the activity with a group discussion or having students build concept maps (Patrick et al. 2023). By incorporating such activities into a course, the experiences provide a greater depth of learning while in class and are then accessible to all students, rather than a select few with extracurricular time to participate. Additionally, only about one out of every three instructors require a textbook, with most instructors using primary literature or other reading resources that have a lower financial burden.

Incorporating DEI topics and teaching practices into Mammalogy is also critical for developing future professionals in a field where working with diverse coworkers and stakeholders is increasingly likely. We suggest that faculty can better support all students and stakeholders by using inclusive teaching practices, incorporating intercultural learning methods associated with the course content, and embedding DEI topics. For example, incorporating an activity or discussion on traditional ecological knowledge, culturally sensitive mammal research and conservation, and the cultural importance or relationships of indigenous people with certain mammals are relevant and important topics that allow for easy and straightforward incorporation of intercultural learning and DEI themes into a Mammalogy class period (e.g., see resources by Kimmerer 2002; Ostertag et al. 2018; Ramos 2018; Waller and Reo 2018; Ahmad et al. 2021). Because readings from the primary literature are heavily used in Mammalogy courses, selecting papers by a diversity of authors and then briefly introducing authors to students with a photo and background information is another low-stakes way to increase DEI in the Mammalogy classroom (see projectbiodiversify.org for resources). Increasing visibility of diverse scientist role models has been shown to help students from underrepresented backgrounds to self-identify as scientists and to increase a sense of belonging in the STEM community (Stout et al. 2011; Lawner et al. 2019).

Finally, embedding skill development and career exposure into courses makes these professional development opportunities accessible to all students and increases the inclusivity of a degree program or curriculum (Yahnke et al. 2023). For example, incorporating case studies into a course allows all students to develop critical thinking skills, while also learning content knowledge associated with relevant, real-world examples (Herreid 1994). The use of CUREs similarly provides all students with the opportunity to develop research skills within a course, and in the case of networked CUREs, to connect and collaborate with other students from across institutions (Connors et al. 2021), all while learning both content and science process skills (Flaherty et al. 2017; Dizney et al. 2020).

Although a much larger time investment, it may also be appropriate to propose and to develop a course to target specific professional career skills for undergraduate students, which would also allow them the opportunity to develop as professionals, while also receiving course credit. Such a course could focus on experiences with direct relevance to careers, like learning how to apply for jobs and graduate school, to network, or to attend a professional conference (Flaherty et al. 2018). Furthermore, because learning and career development are enhanced and supported by the social structure of a course (Bandura 1997), students can find the support from their classmates and instructor beneficial when developing new skills or participating in an activity that may induce anxiety. Thus, the course framework has the potential to help the students socially as well as academically through acquiring credits.

Professional societies like the American Society of Mammalogists play an important role in advancing teaching and supporting their future members by providing the space for discourse and opportunities for members and students to learn from each other and to develop collaborations across institutions. In this Special Feature, we share ideas, resources, and a discussion of the latest teaching pedagogy with a focus on Mammalogy. Our hope is to provide colleagues and Journal of Mammalogy readers with ideas for updating their courses to be more effective and inclusive and in training future mammalogists.

Acknowledgments

Funding for this research was provided by the National Science Foundation under a collaborative grant (2013483, 2013281, 2013308, and 2013320 to HCL, JMD, JV, and EAF). Support for EAF was provided by the USDA National Institute of Food and Agriculture, Hatch Project #1019737.

SUPPLEMENTARY DATA

Supplementary data are available at *Journal of Mammalogy* online.

Supplementary Data SD1.—Survey instrument that was distributed to members of the American Society of Mammalogists during the summer of 2021 to gather information related to the practices and pedagogy used for teaching mammalogy courses. The instrument included 33 fixed-response questions and 11 free-response questions. The survey was developed using questions from the Teaching Practices Inventory with added questions focused on mammalogy content.

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Submitted 17 March 2022. Accepted 2 December 2022.

Associate Editor was Roger Powell.