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Ahead of his time: Joseph Grinnell, natural history, and inclusion and equity in STEM

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Joseph Grinnell designed the Natural History of the Vertebrates (NHV) course at the Museum of Vertebrate Zoology, University of California at Berkeley, over 100 years ago and the course has changed little over these years. In this essay, I connect modern pedagogical and cognitive understandings of what we know leads to success among students to the course. This analysis reveals that the course continues to be successful because it has all the elements of a student-centered, active-learning class that leads to better cognitive gains, better retention, and importantly, proportionately better gains for students from underserved populations. This study will be important for advocates of teaching natural history in biology curriculum.

Joseph Grinnell diseñó el curso de Historia Natural de los Vertebrados (NHV) en el Museum of Vertebrate Zoology, Universidad de California en Berkeley, hace más de 100 años y el curso ha cambiado poco durante estos años. En este ensayo, conecto la comprensión pedagógica y cognitiva moderna de lo que sabemos que conduce al éxito entre los estudiantes del curso. Este análisis revela que el curso continúa siendo exitoso porque tiene todos los elementos de una clase de aprendizaje activo centrada en el estudiante que conduce a mejores ganancias cognitivas, mejor retención y, lo que es más importante, proporcionalmente mejores ganancias para los estudiantes de poblaciones desatendidas. Este estudio será importante para los defensores de la enseñanza de la historia natural en el plan de estudios de biología.

Keywords: Natural history; teaching; active learning; inclusion.

Introduction

In 2017, the Museum of Vertebrate Zoology (MVZ) at the University of California hosted a symposium to celebrate over 100 years of the offering of the "Natural History of the Vertebrates" (NHV) course. The symposium had two foci: 1) to gather people that had taught or taken the course and celebrate its impact on our lives; and 2) highlight the value of natural history education more generally. As a teaching assistant for NHV during my days as a graduate student working under William (Bill) Lidicker, I was delighted to attend and reflect on the NHV course. In particular, I was eager to review the course in light of the *Vision and Change* report (AAAS 2011) that calls for biology educators "to rethink what and how we teach to ensure that the biology we teach engages all students and reflects the biology we practice in the laboratory and in the field." As a counselor for the Council of Undergraduate Research (cur.org) and a Fellow for the Partnerships for Undergraduate Life Science Education (pulse-community.org), I have become an advocate in promoting transformation in STEM education at the undergraduate level and was interested in stepping back and examining the NHV course more carefully. In particular, the structure of NHV has not changed significantly in over 100 years since its founding by Joseph Grinnell and I wanted to overlay modern pedagogical and cognitive understandings of what we know leads to success among students to NHV. What I discovered and reveal in this essay is a course that was successful because it has all the elements of a student-centered, active-learning class that leads to better cognitive gains, better retention, and importantly, proportionately better gains for students from underserved populations. In other words, the course is structured in a way to improve inclusion and equity in the sciences, a topic of great concern to science (see Sarma and Bagiati 2020). This topic is also highly relevant here because Bill was not only a long-time contributor to the NHV course, but he is an academic descendent of Joseph Grinnell through Bill's Ph.D. mentor D. F. Hoffmeister, who is a descendant of E. Raymond Hall, a student of Joseph Grinnell (Jones 1991).

I will organize this essay by first summarizing some of the motivation and recommendations of *Vision and Change* as it relates to biology curriculum and natural history courses specifically, and then describe briefly what student-centered, active learning entails. I will then describe some of the background and details of the NHV course, including Joseph Grinnell's contributions. I will then overlay the course on active-learning expectations to reveal just how impactful this course is for students. Lastly, I will end with a discussion of what this can mean for the future of natural history coursework in biology education and promoting equity and inclusion.

Student-centered, active learning in biology: vision and change. Vision and Change: A Call to Action (V&C; AAAS 2011 resulted from the convergence of many factors including recognition of the need for a biology curriculum

that reflects the current practice of biology, the need to provide a framework for biological literacy in undergraduate biology education, and the need to focus on student-centered (rather than instructor-centered) life science education. After years of workshops and discussions, the V&C contributing authors identified five core concepts as foundations of a biology education that include evolution; structure and function; information flow, exchange, and storage; pathways and transformations of energy and matter; and systems. Additionally, V&C identified several core competencies that are critical for any practicing biologist including the abilities to apply the process of science, to use quantitative reasoning, to use modeling and simulation, to tap into the interdisciplinary nature of science, to communicate and collaborate with other disciplines, and to understand the relationship between science and society.

The VNH course designed by Grinnell, although designed over 100 years ago, includes many of these core concepts and competencies. In 1914, Grinnell intended students to "conduct comparative studies of the conditions in the same areas at different successive times" in order to "bring important generalizations in the field of evolution" (Sunderland 2013). The course was developed before the modern synthesis, so genetics was not emphasized, but evolution, structure and function, and physiology were and remain an important focus of VNH. Grinnell urged his students to record their observations in their notes at the moment of observation so that the memory was not lost. The VNH course was based around the "Grinnellian" method of research that involves a standardized method of note-taking (see below) that is then connected to museum specimens in a highly organized fashion to facilitate access to data associated with each specimen. The methodical fashion in which data were curated led to the MVZ leading modern efforts to digitize natural history records (Sunderland 2013). The VNH course has trained (and continues to do so) students to understand the process of science, how to use quantitative reasoning, and the interdisciplinary nature of science.

Arguably, the most important section of V&C is chapter 3, titled "Student-centered Undergraduate Biology Education." The authors call for undergraduate biology courses that are student-centered and relevant, and that provide authentic research experiences as part of the education. Ideally the courses should be embedded with authentic and frequent assessment procedures that mimic how we approach science, also aptly known as the scientific teaching approach (Handelsman *et al.* 2007). Natural History of the Vertebrates has provided such an active-learning environment where the content is learned in context (Allen and Tanner 2003; Michael 2006) since its inception. To understand this connection, more description of the VNH course is needed.

Natural History of the Vertebrates according to Grinnell. The relevance and importance of this course for the teaching and research of natural history cannot be overstated. As revealed by the thorough analysis of Sunderland (2013), the NHV course was a gateway to Grinnellian natural history, it was the trajectory for the research of the MVZ, and it was and remains the glue for the MVZ community. The last course description of the course before Grinnell's death was the following:

The birds, mammals, reptiles, and amphibians, chiefly of California; identification of species; observational methods in study of behavior and habitat relations; systematics, distribution, speciation. Field work emphasized. (1937-38 General Catalog, University of California, Berkeley)

In modern pedagogical terms, the learning outcomes of such a course are perhaps a bit opaque from this description. A careful examination of his goals for the course, the assignments, and how the course was organized provide a clearer understanding of the learning outcomes. In student-centered learning (also referred to as "Backwards Design," Wood 2009), the course begins with the formulation of broad learning goals and the formulation of specific learning outcomes. Grinnell designed the NHV course as the gateway course to 'Grinnellian' natural history so that students would be able to apply standardized practices to understand adaptations of California vertebrates (Sunderland 2013). The Grinnellian practice includes the following methods:

A field notebook to directly record observations as they are happening.

A field journal of fully written entries on observations and information, transcribed from the notes.

A species account of the detailed observations on chosen species.

A catalog or record of where and when specimens were collected.

While students of VNH rarely collected specimens, the other three elements were relevant as students were led on weekly field trips to surrounding natural areas to observe vertebrate fauna. Often the species encountered in the field were discussed in the lecture portion of the class and encountered in the laboratory, reinforcing the learning. Students also learn basics about fieldwork, using common tools of the trade (field guides, binoculars, live-traps for small mammals). This is important for students whose access to nature is limited and gives them relevant experience for pursuing research apprenticeships or field tech jobs. Teaching students to observe, write, and maintain accurate records of their observations has been maintained as a central focus of this course since its inception. Students' notes are evaluated almost weekly by teaching assistants to ensure that students are acquiring the skills to make meaningful observations (Sunderland 2013).

In active learning, frequent formative assessments are critical to understand if the student is learning. The iterative process of the field notes is an excellent way to see if students are "getting it", and it provides helpful feedback on how to improve. It is remarkable that the instructions for

the field notes remain the same as when Grinnell started the course, and it is interesting to note that Grinnell apparently did not follow his own rules in writing his notes (Sunderland 2013). This may suggest that Grinnell was motivated to do this for grading ease and data extraction (Perrine and Patton 2011), but maybe he also understood the cognitive benefits of the iterative process of note-taking that is such an important element of the NHV course.

The final element of the NHV course is the independent project. Using their acquired scientific observation skills, students design field projects to answer a question based on their field observations over a span of a few weeks. On a personal note, this was always my favorite part of the class, to see how students would struggle to come up with a meaningful question they could approach. I was also impressed because regardless of student's background they could go into the field, be it a park, their backyard, or the Berkeley campus and conduct science. I remember one student who lived in San Francisco and would rise before sunrise to record what species of birds were singing first in Golden Gate Park before showing up at his family's restaurant to work the morning shift. Designing one's own independent project can lead to better confidence and a sense of accomplishment (Lopatto 2010), and such experiences are particularly important for students from underserved populations.

To summarize the connections between the VNH course and active, student-centered learning, the NHV course combines all of the elements of a successful student-centered science course including clear learning, measurable learning outcomes, meaningful formative assessments through iterative field note writing, and an authentic research experience. The course also includes traditional lectures, and summative assessments (lecture and practical exams) that are of course rather traditional.

Why this matters for science education. Numerous biologists have documented and written about the demise of natural history at their institutions including Wilcove and Esner (2000), Wilson (2000), and Schmidly (2005). It is interesting to note that the MVZ has been able to maintain its strong natural history-based research program, due in part to the foundation that the VNH course laid for students and faculty alike (Sunderland 2013). Schmidly (2005) made a strong academic argument for the continuation of natural history in the academy based on its prevalent importance to ecology and evolution, and to the public in general.

While I think these arguments are all relevant, what I discovered in examining the history of the NHV course is a student-centered course that incorporates pedagogies that have been proven to improve retention and graduation rates, particularly among students that are underrepresented in the field of science (Theobald *et al.* 2020). Does not the future of natural history, science, and frankly a functioning society depend on the success of these students? Courses such as NHV that employ active-learning and independent research experiences have a disproportionate benefit for capable students that have suffered though racial inequities in our education system. Such courses also help students from historically marginalized identities in science to see themselves as scientists (*e. g.,* Avraamidou 2020). Administrators may view these courses as expensive and boutique, but can we afford to not fund these courses that are known to improve persistence and success of all students? As Haak *et al.* (2011) demonstrated in a compelling meta-analysis, "a highly structured course design, based on daily and weekly practice with problem solving, data analysis, and other higher-order cognitive skills, improved the performance of all students in a college-level introductory biology class and reduced the achievement gap between disadvantaged and non-disadvantaged students—without increased expenditures." Grinnell may not have fully understood the relevance of his course to equity and inclusion in science and he was certainly a product of the Victorian times (Stein 2001), but we do understand the relevance today and discontinuing such classes is inexcusable and short-sighted. Grinnell must have understood the genius of engaging students in science in meaningful ways, including accepting that science is as much about the unknown as it is about the known (Anderson 2017). So many VNH classes in my experience began with a buzz among students about a new species observation, a new behavior, or an unusual coloration of a common species. I have had the privilege of teaching many types of college science classes in my career, and none compare with the excitement about science when students discover things on their own. The relevance of these types of classes has never been more important.

In honor of William Lidicker and this volume, I want to end by recognizing and celebrating Bill's participation and support of this class for his many years at the MVZ. I recall fondly numerous field trips with him surveying *Microtus* runways to estimate the density of voles, or trapping rodents in Tilden Park. As an academic descendant of Joseph Grinnell, I think it appropriate to commemorate the NHV course and the hundreds of students that Bill taught through this course. It is a lasting and meaningful legacy.

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focus of this essay, I am compelled to acknowledge that there is at least one historical figure associated with the study and teaching of natural history, E. Raymond Hall, that was a proponent of eugenics and published on this topic.

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