Can Science Education Evolve? Considerations on the Pedagogic Relevance of Novel Research Discoveries in Animal Behavior

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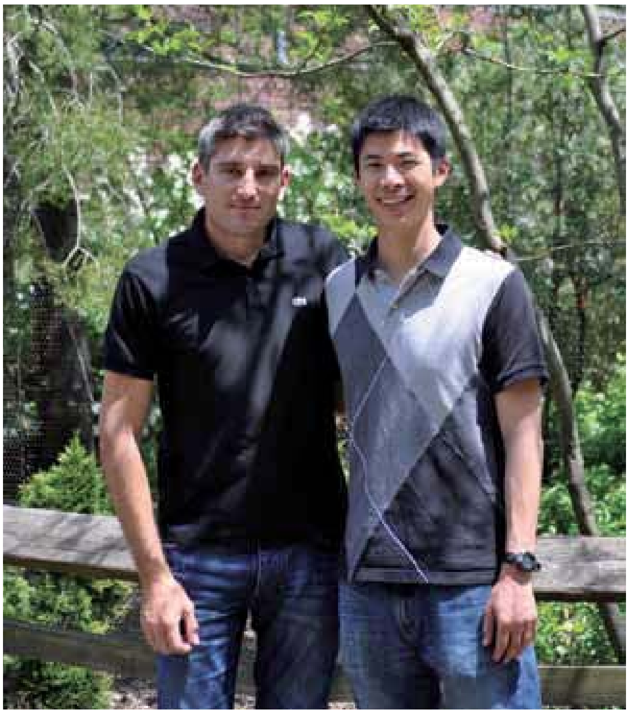
"It's poetry in motion. She turned her tender eyes to me. As deep as any ocean. As sweet as any harmony. But, she blinded me with science."

– Thomas Dolby, "She Blinded Me with Science" (1982)

When we were both two undergraduate students following our first Animal Behavior course in packed auditoria at Southampton College of Long Island University or at Paul Sabatier University of Toulouse, we were fascinated by lectures on sexual selection, anti-predator behaviors, optimal foraging, competition or cooperation in animals. However, times are changing, we are changing and science is changing. While instructors of the discipline still present the proximate (i.e., likely eliciting stimuli) and ultimate (i.e., evolutionary forces) causes of behaviors, it is easy to notice that recent animal behavior textbooks integrate novel topics. For example, within what we consider the latest editions to texts in our field, the authors present new considerations in the field with new ideas that derive from research progress. Today, textbooks incorporate the gene-environment interaction, animal personality and behavioral syndromes, social network theory, social learning and cultural transmission (e.g., the second edition of *Principles of Animal Behavior* by Lee Alan Dugatkin, 2008). Obviously, scholarly achievements over the short history of behavioral research were the building blocks for the evolution of the educational material that were offered to undergraduate and graduate animal behavior students.

In this essay, we want to present our reflection on the need for teachers and mentors who practice animal behavior science at the tertiary level to continuously refine their educational material based on the advancements of the scientific research. In addition, we propose a series of considerations for instructors to assess the pedagogic relevance of novel research discoveries and to include them appropriately into the teaching material. To start, we feel it is important to clearly define what we mean by animal behavior science. Throughout, we will employ the term animal behavior science in its broad and inclusive sense following Bateson's (2012) presentation of *Behavioral Biology:* the scientific domain that incorporates several sub-disciplines with their own distinct perspectives, such as behavioral ecology, evolutionary biology, ethology, sociobiology, psychology or neuroscience.


Guillaume Rieucau (left) and Kevin L. Woo

We advocate that proper application of research studies to regular work with our students can be of significant educational value. Previously, Prince, Felder and Brent (2007) examined the deeply rooted belief that faculty research enriches undergraduate teaching. The authors argued that this claim is seldom, if ever, supported by firm evidence and suggested that the link between research and teaching, especially at the university level, may be weaker than commonly thought. If so, what are the principal reasons of this? Mainly, the two activities have different primary goals and require different skills and basic knowledge (Rugarcia, 1991; Felder, 1994). If research tends to focus on increasing knowledge around a scientific question through novel discoveries, then teaching implies a transfer of knowledge from teachers to students using diverse learning strategies. Moreover, the academic vision of institutions can favor, or sometimes disfavor, what Prince et al. (2007) termed the "Research-Teaching nexus," the observed connection between the two kinds of academic activities. Thus, for example, based on a negative correlation found between research-oriented universities in the United States and several educational indices, Astin (1994) concluded that pursuing curricula in highly research-driven faculties negatively impact students' development; nevertheless, the opposite trend was observed for studentcentered institutions. According to Astin, the two points are strongly interconnected. Generally, research-oriented institutions attempt to recruit scientists with strong research profiles to strengthen their faculty research program instead of scholars who are primarily devoted to teaching. Hence, meeting the expectations of faculty research missions becomes the prime motivation for scholars to place teaching as a secondary task. Even though we share some of the concerns raised by Astin (1994) and Prince et al. (2007), we believe that a successful combination of both aspects of academia is indeed possible and beneficial for students; this, regardless of their educational level or the type of academic institution where they are pursuing their degrees.

Students' interest, personal development and academic success should be the essence of any faculty mission. Institutions should offer the opportunity to students to grasp the reality of the scientific research, during student research projects or by bringing research into the classroom. This should be considered as a significant pedagogic achievement. But, can we ensure a positive interplay between teaching and research? We argue here that this requires a proactive attitude from teachers and mentors by: 1) keeping track of novel advancements of the research in their teaching discipline, 2) determining and extracting the pedagogical substance of new published results, and 3) combining them to the educational platform. To this aim, college environment and culture may encourage teachers' motivation to use research novelties in their teaching materials. In this writing, we want to propose a series of considerations for instructors in animal behavior science to strengthen this *"Research-Teaching nexus."*

A (Brief) History of Nearly Nothing

We are two junior scientists in the field of animal behavior who had followed classic scientific training, defended both master's and Ph.D. theses in research-oriented academic institutions in different countries (United States, New Zealand, Australia, France and Canada) and have post-doctorate experiences in different parts of the world that have contributed to the personal building of our scientific niche. One of us (Woo) now an assistant professor at Empire State College in New York City and the other (Rieucau) is currently a post-doctoral fellow at the Institute of Marine Research in Bergen, Norway. On a regular basis, we communicate the results of our works to the scientific community through scientific publications in peer-reviewed journals or during seminars, congresses or symposia.

Since 2006, we have collaborated on studies around the broad question of animal communication and the evolution of signals employed during animal interactions. Most of our experimental research involves the use of innovative techniques, like video playback and computer-generated animations, to mimic animal partners during social interactions. Lately, their use in testing for visual signal design characteristics has become increasingly popular. We have devoted time and effort to present this experimental approach as an efficient and accurate means to simulate companions and precisely control what focal animals get to observe or experience in term of social stimuli. However, we noticed that some studies developed the animations without any proper standardization; thus, we decided to bridge our interest in signal design and visual animation, and apply a motion algorithm (Analysis of Image Motion) to calibrate design accuracy in computer-animations. Using an experimental approach, we are exploring visual signals employed by the Jacky dragon *(Amphibolurus muricatus)*. For our first collaboration, we published our study in *Behavioural Processes* (Woo & Rieucau, 2008).We have since continued to use the Jacky dragon as a model for signal design and have published three manuscripts in diverse scientific reviews: *Behavioral Ecology & Sociobiology* (2011), *Ethology* (2012), and *Ethology Ecology & Evolution* (2013). Most recently, we extended our collaboration to another system investigating, this time, the microevolution of alarm calling in helmeted guinea fowl *(Numida meleagris)* in the urban environment. This research project is supported by Empire State College. We will conduct our first experiments in spring 2013 at the Prospect Park Zoo, Brooklyn, N.Y.

In 2008, our collaborative scientific journey slightly deviated from its research-focused path when we co-supervised an undergraduate student during her student research project at Southwestern University, Georgetown, Texas. At this time, Woo was a visiting assistant professor at the Department of Psychology at Southwestern University, while Rieucau was finishing his Ph.D. thesis at Université du Québec à Montréal, Québec, Canada. Our mentee was working on a project to develop a computer-generated mummichog *(Fundulus heteroclitus),* and to use the animation in social learning and facilitation experiments in fish. Collectively, we helped her create the animation and design-staged experiments (Figure 1). We developed a study to employ the animation in a social context, where most animation experiments typically use a single live individual with a single animation. We used this technique to test for the interaction between the numbers of social foragers versus the presence-or-absence of a predatory fish. Ultimately, she presented this work at the 2008 Southwestern Psychological Association Conference in a talk entitled, "Building Nemo: The Development of a 3D Animated

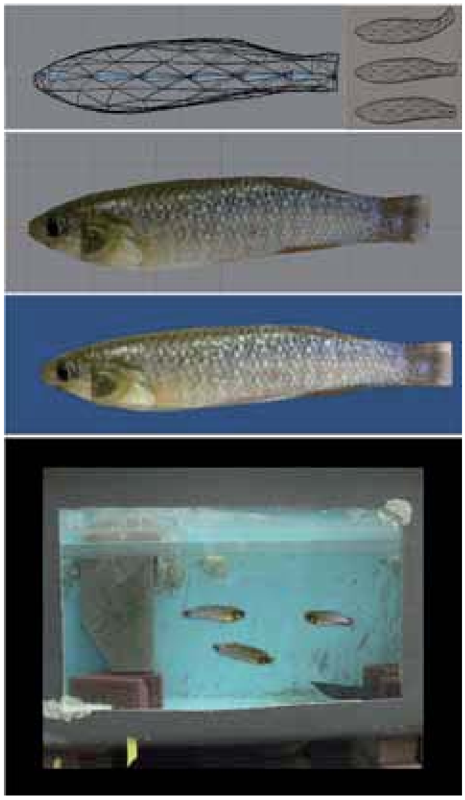


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Figure 1. Screen capture of animated mummichog *(Fundulus heteroclitus)* during the first co-supervision of an undergraduate student.

Mummichog to Study Schooling Behavior," which was co-authored by us, and Dr. Jesse Purdy (Southwestern University).

At that time, we believed that we would mostly gain from the research outcome, *per se,* of this project. Retrospectively, as much success as we encountered with this experiment, we gained a lot more valuable experience from interacting and supervising our mentee. We now believe that the reason was that for the first time in our careers, we had to re-evaluate the way we think about and do scientific research to meet our mentoring duties. The biggest challenge faced was to develop and include an "educational" component into the research process itself, something that we were not so used to at that time.

The first step of the process was to define the scope of the student project. We refined the research question that we wanted to address in such a way that it became pedagogically meaningful. Therefore, we determined the theoretical concepts that were important for our mentee to grasp by taking into account her knowledge in the field. To do so, we felt very important to have open discussions (using the Internet platform) to clearly distinguish our mentee's interests and expectations. It was, for her, a good experience to be engaged in scientific discussion around a research question. Once the scientific question and the pedagogic goal were determined, we engaged our mentee in the readings of selected scientific articles and textbooks chapters. We offered some "supervised" freedom to our mentee, an active learning strategy that encourages innovation as opposed to adopting rote protocols. We helped her to formulate the working hypotheses and predictions for the project and we were very careful to guide her in this process in such a way that the general hypothesis that was developed met the pedagogic achievements fixed for her student-project. While we provided continuous external advisement during the development of the experimental design and the building of the 3-D fish animations, this followed a "trial-and-error" process for her – an everyday face-off to all scientists. Thus, in our mentorship, we created a step-wise approach for her to employ the scientific method, and to merge theory and application, as she designed her project.

Through our own academic training, we clearly navigated academia through a traditional path. However, as we reflect upon our actual practices when we teach in the classroom, and directly mentor a research student, we noticed significant variations that differ from how we learned to how we impart knowledge. Moreover, as we reviewed our own pedagogical evolution, we recognized an apparent disconnect in the system. Below, we highlight three main considerations that aim to reduce the gap between scientific research progress and science education.

I. Keeping Track of Research Novelties

Indubitably, the pool of scientific knowledge is growing day-after-day. Researchers in biological sciences rely on the advancements of the ongoing scientific research to address meaningful questions that allow others to develop new hypotheses to test, refine or sometimes challenge classical ideas or theories. Recently, the rapid improvement in science communication, especially with the exceptional explosion of the World Wide Web, ensures an incessant flow of research information to the scientific community. The research field of animal behavior does not stand outside of this reality. New studies based on empirical or theoretical work are published every day in many peer-reviewed scientific journals that range from broad perspective and audience journals (e.g., *Nature, Science, Current Biology, PNAS, Ecology Letters, PloS ONE, Journal of Animal Ecology*), core animal behavior journals (e.g., *Animal Behaviour, Behavioral Ecology, Behavioral Ecology and Sociobiology, Ethology, Behavioural Processes, Behaviour*) to topic-specialized journals (e.g., *Ibis, Copea, Journal of Fish Biology*). Web search engines, open access journals, digital libraries and content alerts have revolutionized how scientists access scientific information.

However, with this permanent and somehow overwhelming flow of information, the ability to keep track of the latest published research results in an accurate manner is a laborious task that requires rigor and significant time investment to collate up-to-date scientific information. Recent research information must be accessible to the scientific community through conventional publications or other communication pathways (symposiums, workshops, media RSS feeds), but it also needs to be assessed by critical readers who will evaluate the value of its contribution to their field of specialization. The peer-review system, often criticized due to its lack of transparency, is a necessary process to ensure that novel research information will reach the scientific standard of scientific robustness required for publication. Then, every new piece of research information will help scientists better understand *why* (referring to the function and evolution of behaviors) and *how* (referring to the development and mechanisms that underlie the behaviors) animals behave the way they do. However, it is important to keep in mind that assessing the *scientific value* of a scientific contribution and assessing its *pedagogical content* are two different exercises.

Current interests in animal behavior science are changing with the rise of new areas or questions of interest, such as the next "hot topic." Thakur, Mane, Borner, Martins and Ord (2004) mapped the evolving interests in animal behavior. The authors analyzed the research areas of over 2,000 articles published in 1994, 1997 and 2000 in a core set of journals in the animal behavior domain (e.g., *Animal Behaviour, Behavioural Processes, Behavioral Ecology, Behavioral Ecology and Sociobiology, Journal of Ethology, Journal of Insect Behavior, Applied Animal Behavior Science*). Their results revealed changes in the general interests of published articles over the years with a reported focus on parental behavior, feeding behavior and animal learning in 1994, an observed switch toward sexual and social behaviors in 1997, and toward mating, nesting and foraging behavior-related questions in 2000. Classical topics taught in animal behavior at the undergraduate and graduate levels address sexual selection, optimal foraging, communication, parental care, competition, parasitism, aggregation, cooperation, learning and present classical approaches such as field observation, experimentation *in situ* or in a semi- or fully-controlled environment, theoretical modeling as game theory (producer-scrounger model, hawk/dove game, prisoner's dilemma) or the optimality theory (optimal foraging, central-place foraging). Even though new questions of interest in the field are regularly introduced to the teaching material, they generally lag behind research advancements.

Over the last decade, animal behavior science has undergone a major shift. Indeed, the study of between-individual differences and variations in behavior over time and across ecological contexts has received growing attention. Commonly, it is admitted that animals adjust their behavioral responses when in specific situations in a way that minimizes their costs/benefits ratio (Krebs & Davies, 1993). Selective pressures were thought to act as an erosive force on genetic (and phenotypic) variations of traits expressed in a population and due to long-term effects, the mean value of a (behavioral) trait should reach an optimum. Thus, the adaptive expression of a (behavioral) trait in a particular situation should only be optimal if it allows individuals to maximize their fitness. Behavioral flexibility (or behavioral "plasticity") is expected to be unlimited, immediate and reversible (Sih, Bell, & Johnson, 2004). Generally, behavioral plasticity is presented as the principal adaptive cause of behavioral variations observed at the population or specie levels (Dall, Houston, & McNamara, 2004). Interestingly, animals often express a very limited behavioral plasticity and vary in consistent ways in their reactions toward similar external conditions (Clark & Ehlinger, 1987). Recent attention in the investigation of variations around the mean behavior of the population has promoted the study of "animal personalities" (Gosling, 2001; Réale, Reader, Sol, McDougall, & Dingemanse, 2007), also presented as behavioral syndromes (Sih et al., 2004) or temperament (Boissy, 1995), and their ecological and evolutionary consequences (Wolf & Weissing, 2012). Differences, consistent over time and situations, between individuals in the expression of their behaviors are referred to as "personality" and have been reported across a large range of species and reach various ecological settings (as foraging, antipredator, exploratory or aggressive behaviors). This is now considered a widespread phenomenon in the animal kingdom. Traditionally, individual differences in behavior were only considered as "noise" around the mean value of a population with no real evolutionary importance. However, to date, the study of animal personality is of prime importance with many remaining unanswered questions. As a consequence of intensive research in personality and behavioral syndromes, a growing number of researchers have been interested, and actually quite intrigued, by questions around the proximate and ultimate causations of personality differences in animal populations. If previous research in the field of animal personalities has mostly focused on the relationship between personality traits and fitness of individuals using theoretical or empirical approaches, we noticed a subtle shift toward a broader and integrative examination of the phenomenon with the current consideration of the important consequences of animal personalities for ecologically and evolutionary processes (Wolf & Weissing, 2012). Animal personality was a controversial topic in the early 2000s, and at the time, it met resistance from a part of the scientific community. Animal personalities finally entered students' textbooks, a good example of which is the recent addition of a chapter entirely devoted to this topic in the popular *Principles of Animal Behavior* (Dugatkin, 2008).

The field of animal personality is not an isolated example, and new growing areas of research are starting to find their place in the pedagogical material used by teachers in animal behavior science as social learning and cultural transmission. Numerous studies have explored the mechanisms and functions of social learning and the use of social information that is thought to afford the first building block for the evolution of culture in animal society (Galef & Giraldeau, 2001; Danchin, Giraldeau, Valone, & Wagner, 2004; Laland, Atton, & Webster, 2011; van Schaik & Burkart, 2011).

Recently, both empirical and theoretical efforts have focused on unraveling the circumstances under which animals use incorrect social information and consequently decide wrongly to adopt maladaptive behavior. For instance, evidence shows that social animals can disregard even reliable personal information and copy the erroneous behavior of others (Rieucau & Giraldeau, 2011). Such herd-like phenomena, called informational cascades, have been studied by economists such as Bikhchandani, Hirshleifer and Welch (1998) and have been reported to be widespread in human societies in which decisions are made with total disregard to the individuals' personal knowledge. Then, it results in individuals "blindly" copying the observed decision of predecessors (Bikhchandani et al., 1998). These informational cascades have been proposed as a coherent explanation for a number of large-scale explosive copying events observed in humans, such as market crashes in economics, new fashion styles or panic rushes in crowds but also in animal societies as the accumulation of thousands of colonial birds in night roosts, mate choice copying and collective escape behaviors in bird flocks or fish schools (Giraldeau, Valone, & Templeton, 2002).

The transmission of information from parents to young or between non-related individuals about the quality of the environment, sexual partners, food resources, presence or absence of any kind of danger are some of the evidence than animals can learn from others – sometimes wrongly. This social information is non-genetically coded, compared to the genetic information that is coded by DNA, and is conveyed both vertically (across generations) and horizontally (within generation) and provides the essential "vector" for cultural transmission (Danchin et al., 2004) in both animals and, of course, humans. The increasing interest in the emerging topic of cultural transmission and its evolutionary consequences (i.e., cultural evolution) shows in its recent presence in several textbooks frequently used in animal behavior classes such as *Behavioural Ecology* by Danchin, Giraldeau and Cézilly (2008, Chapter 20, 693-726). Hence, students following animal behavior courses can be introduced to the study of animal culture and the role of cultural inheritance in evolution, a role that was underestimated for long time.

New technological opportunities to observe and quantify behaviors *in situ* (e.g., video playback techniques, computer generated 3-D animations, sonar imaging and acoustics for aquatic animal species, highdefinition video recording, satellite tags for migratory species), in advanced computing and large data processing, evolutionary (e.g., genetic algorithms) and collective behavior simulations (e.g., collective responses tracking), as well as in the development of molecular (e.g., database of gene sequences and expression) and physiological (e.g., respiratory, stress hormones) tools allow researchers to test new hypotheses in animal behavior. Undoubtedly, these new methods are useful tools that researchers can use regularly to better understand animal behavior. They also illustrate the need to include them in current educational material.

II. Evaluating the Pedagogic Value of Novel Research Information

Research information should be seen as a primary component in the development of effective pedagogic activities. But it is a fact: not all new scientific results have educational relevance. Thus, when facing the desire to add a newly published result in their teaching material, instructors and mentors must keep in mind that pragmatism is a virtue. We emphasize again that evaluating the scientific content of a research study is not the same as evaluating its educational content. Here, we formulate a series of questions that would guide teachers toward determining and extracting the pedagogical substance of research novelties and finally how to incorporate them in an effective way into the education platform (Table 1).

What is the current foundational knowledge in the field?	Questions concerning the research novelty
To what extend will the new research information strengthen the current course material? Anecdote or new course chapter?	
If it challenges classical ideas, do I consider legitimate to include the new research information into my teaching material?	
Who are my students?	Focus on the students
What are my students' goals?	
What prerequisite knowledge my students should have to grasp the new information?	
Does the new research information require specifics that students do not need to know?	
How do I identify and ask questions that derive from published studies or model systems?	Questions about the pedagogical platform utilized to present the new research information
Will I introduce the new information during formal lectures or laboratories?	
How do decouple, yet complement theory and practical application?	
How do I reinforce critical thinking, analytical, and interpretive approaches to research problems in the discipline?	
Do I, as the instructor, teach to specific content, or promote the use of strategies beyond prescription?	

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Table 1. Our questions on the evaluation of research questions for instruction as conceived from three points of view: the research, the student and the pedagogic value.

III. A Broad Perspective: The Natural Selection Process of Science Education

Estimates from the U.S. Department of Education, National Center for Educational Statistics (2012) suggest that in 2010, there were approximately 21 million students enrolled in undergraduate institutions. From this cohort, approximately 1.7 million students had enrolled in post-baccalaureate degrees across all disciplines, which include master's and Ph.D. programs (NCES, 2010). Furthermore, in some programs, there is a 50 percent attrition rate for Ph.D. candidates (McAlpine & Norton, 2006). Reflective of the sciences, these statistics also indicate a shift in gender and ethnic matriculation, which is increasing among women (Sax, 2000) and other minority groups (Oakes, 1990). This shift also garners a greater perspective and acceptance of gender-balanced and minority-balanced programs (Lopatto, 2004). Hence, the number of undergraduate students who earn their bachelor's degree, compared to those who likely advance and complete their Ph.D.'s, indicates a huge disparity in education. Moreover, this difference also suggests educational strategies that likely cater to certain strengths of students, and likely segregate them from a weaker pool of candidates. This is currently the reigning strategy for recruiting top intellectual talent for post-graduate programs. However, we question this approach and ask whether the real premise of this strategy is to support a relatively small number of students in advanced science work and deny the education of science-related skills to the majority of undergraduate students who become discouraged. We acknowledge that many other factors, such as a decision not to attend graduate school, personal conflicts or medical issues, just to highlight some common reasons, may prevent an undergraduate student from pursuing a graduate degree.

The quest for a degree in the sciences reflects the process of natural selection. Though, even if we consider a Darwinian approach, undergraduate science programs tend to favor students who are able to achieve high marks on fairly standardized assessment tools, such as exams (e.g., multiple-choice) and laboratory reports. Few conventional courses deviate from this prescription, especially in institutions with a large undergraduate enrollment, as it allows instructors and their teaching assistants to grade the material systematically and swiftly, and hence, from their perspective, to assess students more efficiently. Here, efficiency is not a function of student learning, but of grade-processing. Moreover, this approach identifies specific benchmarks for excellence, adequacy and failure across a traditional "A-F" grading system. It segregates strong from weak students, and ignores the likely causes for the disparity in performance. Stronger students may have likely developed strategies for success, while those who fared worse may never change. Exemplifications of "winner and loser effects" (Dugatkin, 1997) continue to reinforce strategies to a wider bimodal distribution. However, that still leaves a significant portion of the population who fair adequately, one in which reflects a bell curve (Herrnstein & Murray, 1996). The small percentage of students who excel might likely progress to a graduate degree, the middle likely receiving (but not maintaining) a base-level of knowledge, and the rest facing science-learning extinction!

What about this "middle-class"? Typically, a gap in knowledge occurs between traditional freshman-to-senior level instruction and learning. For example, students in introductory Biology are often taught the scientific method, how to find and cite research from primary research journals, and format laboratory reports in a scholarly manner. However, many mid-level biology courses cease to reinforce these skills, and simply expect students to master them. Somewhat ironically, not all students do, and this is evident by the success rate of biology graduates with high grade point averages (GPAs) and the selection criteria that makes them competitive applicants as candidates for graduate programs. Thus, success demands knowledge from students that they do not necessarily have.

The quest for a degree in the sciences reflects the process of natural selection.

The goal for every laboratory is to advance scientific knowledge. However, to discover phenomena about the natural world is to compete. Both Schoener (1983) and Connell (1983) conducted independent meta-analyses of all papers published in ecological journals at the time, and found an overwhelming bias across the articles that were sampled demonstrating competition, either inter- or intraspecific. Publications are the "currency" of science, and there is an interaction between quality and publication of research. Potential post-graduate degree supervisors acquire students who are likely capable to improve the currency of the laboratory. The employment of the scientific process is to acquire new knowledge; yet, Rosenthal (1979) noted that nearly 95 percent of all research studies end in non-significant results. Failing to reject the tested hypothesis (then, accepting the null hypothesis) is inherently a result, but there is a bias to believe that all science produces significant results, and that only significant results are published.

Perhaps, in pairing with a Darwinian approach, we could argue that the graduate atmosphere is Machiavellian. There is a pressure to publish or perish, especially for institutions whose currency is dependent on output. Retention rates in the United States for graduate programs vary widely (Nerad & Miller, 2006). Graduate students are expected to employ basic experimental techniques and design innovative techniques to solve problems. The failure to "produce" may result in retribution by their supervisor, ostracizing by the scientific community and inability to maintain support from the institution to continue the degree. At this academic level, there is an obvious conundrum: How do we expect graduate students to employ innovation if they have not mastered experimental techniques in basic biology and/or ecology? Aside from their own theses, graduate students may only gain additional training through teaching assistantships. However, many research-driven institutions invest heavily in individuals who are employed to conduct research, and do not invest sufficiently in the education of undergraduate students (Putnam & Borko, 2000).

How do we ensure that learners are gaining foundational knowledge in the sciences, while, at the same time, incorporating new discoveries? This is the gap. Peer-reviewed journals highlight modifications of methodological approaches for new experimental designs to answer questions. Yet, few of these methods are ever transferred to college-level laboratories or courses.

Conclusion

It is often assumed that one should not ask a scientist for answers, as you will only yield more questions. *"Why should we care?"* In this essay, we discussed several issues with the current pedagogical approach for engaging students in science, and more specifically, the discipline of animal behavior. *"How do we make students care?"* We can radically change the relationship between learner, mentor and content, but that does not guarantee success. Consequently, we acknowledge that we need to include one critical component to our discussion: *A posteriori* evaluation of the effectiveness and application of alternative approaches to science education. *"How do we measure success?"* We need a reliable measure for ensuring the success of new pedagogical paradigms. Here, we merely introduce some initial thoughts on the current trajectory of science education, and indeed, aim to further understand and perhaps even improve upon this imperfect relationship.

Acknowledgements

Rieucau and Woo would like to thank the Junior Team C.T.F.D. We also thank Albert Castelo for his useful comments on our article. Rieucau was supported by the Norwegian Research Council (grant 204229/F20).

References

Astin, A. W. (1994). *What matters in college? Four critical years revisited.* San Francisco, CA: Jossey-Bass Inc.

Bateson, P. (2012). Behavioural biology: The past and a future. *Ethology, 118,* 216-221.

Bikhchandani, S., Hirshleifer, D., & Welch, I. (1998). Learning from the behavior of others: Conformity fads and informational cascades. *Journal of Economic Perspectives, 12,* 151-170.

Boissy, A. (1995). Fear and fearfulness in animals. *Quarterly Review of Biology, 70,* 165-191.

Clark, A. B., & Ehlinger, T. J. (1987). Pattern and adaptation in individual behavioral differences. In P. P. G. Bateson, & P. H. Klopfer (Eds.), *Perspectives in ethology* (pp. 1-47). New York, NY: Plenum Press.

Connell, J. H. (1983). On the prevalence and relative importance of interspecific competition: Evidence from field experiments. *The American Naturalist, 122,* 661-696.

Dall, S. R. X., Houston, A. I., & McNamara, J. M. (2004). The behavioural ecology of personality: Consistent individual differences from an adaptive perspective. *Ecology Letters, 7,* 734-739.

Danchin, E., Giraldeau, L.-A, & Cézilly, F. (2008). *Behavioural ecology.* New York, NY: Oxford University Press.

Danchin, E., Giraldeau, L.-A., Valone, T. J., & Wagner, R. H. (2004). Public information: From nosy neighbors to cultural evolution. *Science, 305,* 487-491.

Dugatkin, L. A. (1997). Winner and loser effects and the structure of dominance hierarchies. *Behavioral Ecology, 8,* 583-587.

Dugatkin, L. A. (2008). *Principles of animal behavior* (2nd ed.). New York, NY: W. W. Norton & Company.

Felder, R. M. (1994). The myth of the superhuman professor. *Journal of Engineering Education, 83,* 105-110.

Galef Jr., B. G., & Giraldeau, L. -A. (2001). Social influences on foraging in vertebrates: Causal mechanisms and adaptive functions. *Animal Behaviour, 61,* 3-15.

Giraldeau, L. -A., Valone, T. J., & Templeton, J. J. (2002). Potential disadvantages of using socially acquired information. *Philosophical Transactions of the Royal Society B: Biological Sciences, 357,* 1559-1566.

Gosling, S. D. (2001). From mice to men: What can we learn about personality from animal research? *Psychological Bulletin, 127,* 45-86.

Herrnstein, R. J., & Murray, C. A. (1996). *The bell curve: Intelligence and class structure in American life.* New York, NY: Free Press Paperbacks.

Krebs, J. R., & Davies, N. B. (1993). *An introduction to behavioural ecology* (3rd ed.). Oxford, UK: Blackwell Scientific Publications.

Laland, K. N., Atton, N., & Webster, M. M. (2011). From fish to fashion: Experimental and theoretical insights into the evolution of culture. *Philosophical Transactions of the Royal Society B: Biological Sciences, 366,* 958-968.

Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. *Cell Biology Education, 3,* 270-277.

McAlpine, L., & Norton, J. (2006). Reframing our approach to doctoral programs: An integrative framework for action and research. *Higher Education Research & Development, 25,* 3-17.

Nerad, M., & Miller, D. S. (2006). Increasing student retention in graduate and professional programs. *New Directions for Institutional Research, 92,* 61-76.

Oakes, J. (1990). Opportunities, achievement, and choice: Women and minority students in science and mathematics. *Review of Research in Education, 16,* 153-222.

Prince, M. J., Felder, R. M., & Brent, R. (2007). Does faculty research improve undergraduate teaching? An analysis of existing and potential synergies. *Journal of Engineering Education, 96,* 283-294.

Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher, 29,* 4-15.

Réale, D., Reader, S. M., Sol, D., McDougall, P. T., & Dingemanse, N. J. (2007). Integrating animal temperament within ecology and evolution. *Biological Reviews, 82,* 291-318.

Rieucau, G., & Giraldeau, L. A. (2011). Exploring the costs and benefits of social information use: An appraisal of current experimental evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences, 366,* 949-957.

Rosenthal, R. (1979). The file drawer problem and tolerance for null results. *Psychological Bulletin, 86,* 638-641.

Rugarcia, A. (1991). The link between teaching and research: Myth or possibility? *Engineering Education, 81,* 20-22.

Sax, L. J. (2000). Undergraduate science majors: Gender differences in who goes to graduate school. *The Review of Higher Education, 24,* 153-172.

Sih, A., Bell, A., & Johnson, J. C. (2004). Behavioral syndromes: An ecological and evolutionary overview. *Trends in Ecology & Evolution, 19,* 372-378.

Schoener, T. W. (1983). Field experiments on interspecific competition. *The American Naturalist, 122,* 240-285.

Thakur, S., Mane, K. K., Börner, K., Martins, E., & Ord, T. (2004). Content coverage of animal behavior data. *Visualization and Data Analysis, 5295,* 305-311.

U.S. Department of Education, National Center for Education Statistics. (2012). *Digest of education statistics, 2011.* Retrieved from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2012001

van Schaik, C. P., & Burkart, J. M. (2011). Social learning and evolution: The cultural intelligence hypothesis. *Philosophical Transactions of the Royal Society B: Biological Sciences, 366,* 1008-1016.

Wolf, M., & Weissing, F. J. (2012). Animal personalities: Consequences for ecology and evolution. *Trends in Ecology and Evolution, 27,* 452-461.

Woo, K. L., & Rieucau, G. (2008). Considerations in video playback design: Using optic flow analysis to examine motion characteristics of live and computer-generated animation sequences. *Behavioural Processes, 78,* 455-463.

Woo, K. L., & Rieucau, G. (2011). From dummies to computer-animated stimuli: A synthesis of techniques employed to stage animal interactions. *Behavioral Ecology and Sociobiology, 65,* 1671-1685.

Woo, K. L., & Rieucau, G. (2012). Aggressive signal design in the Jacky dragon *(Amphibolurus muricatus):* Display duration and frequency affect efficacy. *Ethology, 118,* 157-168.

Woo, K. L., & Rieucau, G. (2013). Efficiency of aggressive and submissive visual displays against environmental motion noise in Jacky dragon *(Amphibolurus muricatus). Ethology Ecology & Evolution, 25,* 82-94.

How to Write a Poem

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Everything you're about to hear is happening just the way I tell it.

It's night. I'm asleep in my bed but I'm not in my bed. I'm dreaming there's an enormous, bloated, satiated bear, slumbering belly up in my mother's place, taking over a whole room with his snores swelling and sinking and rough fur roughing up the furniture. I'm afraid – I know that when he gets hungry again, there will be trouble.

Like all bears, he has very long, strong, sharp, claws, but unlike any other bear, his back is the color of an Irish setter but his belly is the color of clotted cream. I've never heard of a bicolor red bear, and, this bear has a long tail to boot, bristling fur energetically like the fur on the tail of a husky.

When I wake up, I'm supposed to think about what the whole thing means to me, how to describe it, all the things that eventually turn up between the lines of poems. But I spend more time wondering about the bear's strange appearance than anything else, because anything else all seems a vain pursuit. The symbolism, I'm sure, will elude me, and the images are too utterly concrete to be anything but themselves.

It's afternoon, the same day, one of those days that day battles night from dawn to dusk in a dark gray sky that's a presence, not an absence, the threat of a storm mixed with light so yellow it turns green leaves gold and gold leaves orange. I'm walking in the park and see a tree that has seedpods shaped like miniature rounded pine cones, yet no needles. I wonder if it is a dead evergreen, clinging to posterity. I wonder if there's a kind of evergreen that sheds its needles.

There's a voice behind me, "See something you recognize?"

Without turning around, I answer. "This tree has these things like pine cones, but no needles. So, I wonder if it's a dead evergreen, or a kind of evergreen that sheds its needles or what."

"Look close," a hand reaches over my shoulder and pulls a branch near my face, "these are buds. I'm seein this for the fourteenth year now."

Yes, they're buds.

I turn to look at the speaker. He's large, bearish actually, and I see he's holding a leash. At the end of the leash stands a husky the color of an Irish setter with a belly the color of clotted cream and a long tail bristling fur.

"Do you like bears?" I ask.

"I don't know much about them; just they have very long, strong, sharp claws. Why'd you ask?"

"Last night I dreamt about a bear who was the color of your dog, red with a belly the color of cream, and a long tail, just like your dog's."

"Must've been a sign," he says. "Sometimes something doesn't feel right, maybe it's anger, maybe it's sexual. Everything else is fine, you're doin fine, but because of this something you open to someone, someone who when they get into it, get into what's botherin you, they don't stop there but start diggin around and eatin you up, messin with what was fine. You can't open like that. What you gotta do is use your own emotions, you gotta work em yourself."

He's saying more, but I'm still digesting this. He stops.

Starts again: "My father, he was as light as you. My mother, she was the dark one, a Puerto Rican Indian."

"Taino?"

"Yeah, Taino."

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I look at him carefully, he looks at me. I can't tell you what he saw, and I can't tell you what I saw, but many would describe him as a middle-aged man with a belly, missing quite a few teeth. Dark skin, black eyes, wavy black hair, rough tired clothes.

"What you told me – you learned it the hard way," I say.

"Yeah."

"Dreams," I say. "Everyone thinks they're about something inside of you, but sometimes they're about something outside of you. Like, in this case, when someone bearish with a red and cream husky comes along, pay attention to what he says."

We walk and talk a little longer and he says he has to go and he takes a left and walks away. I take a right and go to the flower shop and buy three white carnations and offer them to the God of Chance. I work for a few hours, then I get dressed to go to a bona fide literary event; my poetry teacher's in town to sign books. As I walk out the door and turn the corner, he turns the corner, too, and we're face to face again.