Putting the "Ph" back into "PhD": framing graduate research in a theoretical context



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Although we graduate students strive to acquire the title of PhD, are most of us qualified to be a Doctor of *Philosophy* when we graduate? A philosophy essentially is a reasoned point of view of how to approach the world, whereas a philosophy of science determines how we seek to understand the world. Therefore, philosophy provides the foundation for the method(s) by which ecologists test hypotheses and develop theories. Yet, as graduate students, we often overlook the rich philosophy of science literature in ecology and how our particular philosophy shapes our definition of theory. At the beginning of graduate school, we decide on interesting questions to focus our research (see Bump [2007] for suggestions), and forge ahead with literature searches, experimental design/implementation, and data analysis. Throughout this process, however, we may lose sight of how our research fits with established theories, an understanding that is essential for productive graduate research.

For a recent seminar, we, the authors, read and evaluated Pickett *et al.*'s *Ecological understanding: the nature of theory and the theory of nature* (Pickett *et al.* 2007). Few in the class had a philosophy of science background and, consequently, some students had difficulty describing how existing theory(ies) inspired questions, hypotheses, and experiments. Although we could name the basic theories underlying our respective research, many of us did not understand how different components of these theories were used in our own studies. Pickett *et al.* (2007) suggest breaking theories into their constituent parts – *concepts*, *facts*, *assumptions*, *models*, and *laws* – to understand how they relate to our own hypotheses. Below, we suggest a few critical questions, designed to aid students in this process, that were derived from our seminar discussions.

What explicit theories have inspired my hypotheses? Are any components of these theories weakly substantiated? We often accumulate a laundry list of citations that inspire the development of our hypotheses, but seldom identify the constituent parts of different theories from which these hypotheses are formed. A strong research project should clearly identify the origin of the constituent parts (as per Pickett *et al.* 2007) that form the hypotheses. We may then be able to identify any parts that are weakly substantiated, and consequently design their research to address these gaps.

How do components of the various theories involved in my research fit together to form my hypotheses? Learning how the parts of many theories interact to form interesting hypotheses can show students how their research fits into multiple subdisciplines of ecology. For example, a hypothesis from one of our dissertations (CMP) is that herbivores will prefer to consume the more rapidly decomposing leaves associated with tree-fall gaps than to consume similar leaves elsewhere. This hypothesis was formed by integrating *concepts* of optimal foraging theory, *models* from plant community theory, and *assumptions* about leaf chemistry/decomposition from ecosystem theory. Recognizing how different subdisciplines of ecology impact our research allows us to feel more comfortable talking with different types of ecologists, and could result in greater post-graduation marketability.

How can the results from my research be generalized? Experimental studies take place at particular locations for limited time periods. By generalizing our results, we strive to make our research applicable at broader scales. Before gathering data, we need to think about the scope (space, time, and processes) to which our results will apply. These parameters can be defined by the *facts* and *concepts* that have informed the hypotheses. For instance, one of us (DMC) investigates how cougars influence the foraging strategies of ungulate prey. One fact informing this research is that cougars are solitary ambush predators, whereas many *concepts* from foraging theory have been examined using ungulate responses to pack-hunting predators (eg wolves). Therefore, results obtained by testing DMC's hypotheses may not only apply to ambush predators of vastly different systems, such as those in freshwater or marine habitats, but could also expand our understanding of how prey species respond to different types of predators in the same systems. Knowing how to generalize results is crucial for producing research publications and obtaining research funding. We have found that generalization is much easier after the *concepts* and *facts* contributing to questions have been identified.

What components of the existing theories are changed by the generalization of my results? As scientists, we get particularly energized at the prospect of our research influencing theory. But as students, this goal seems unachievable. If we understand how our hypothesis was derived from components of existing theories, we can see how our results may change those theories. For example, a general *concept* in predator–prey theory is that the presence of predators induces a reduction in prey activity, which subsequently promotes the growth of the prey's food resource. This *concept* assumes that prey foraging activity is correlated with feeding effort, but research by one of us (MJM) has shown that prey can adjust other components of foraging – such as search effort – in response to predators, while maintaining constant feeding rates. This fine-tuning of prey behavior may preclude any indirect positive impacts of predators on the food resources of prey. Even as graduate students, our dissertations have the ability to modify existing theories, but only if we understand how our hypotheses were derived from theories.

These questions are meant to provide a starting point for students beginning their research. We hope that by addressing these questions, you will gain the ability to build hypotheses from theory, identify gaps in existing theory, and generalize results appropriately. If you are unfamiliar with the relationship between the philosophy of science and ecological theory, we recommend that you broaden your thinking by exploring some of this wide literature (see WebPanel 1 for a list of relevant examples). Framing graduate research in a theoretical context will strengthen projects, increase the impact of your work, and makes you more marketable post-graduation. And after all, don't we want to deserve the "Ph" in that long-sought-after title?

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Faculty response

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The view expressed by Prather and colleagues regarding the role of philosophy in helping to structure and frame research questions is, in my opinion, right on. All scientific advances come from an understanding of the conceptual underpinnings, the literature, and knowledge currently amassed, followed by asking the critical questions necessary to fill in the knowledge gaps. This can only work if one starts – from the outset – with an understanding of the general theoretical framework, and builds a research program from there. Ecologists often argue that, because of the multidisciplinary nature of ecology, there is no general theoretical framework for ecological questions, and therefore one's research approach cannot fit into a framework such as that outlined by the students here. I think that argument is flawed, as do many recent authors (Lange 2005; Pickett *et al.* 2007; Scheiner and Willig 2008; Dodds 2009). The four questions outlined by Prather and her coauthors provide a very compelling approach for framing one's research, and are not limited to dissertation research. This approach will also likely help to address a critical problem in ecology, that of ambiguous terminologies (see Madin *et al.* 2007). By asking how various components of other theories fit together (the second question suggested by the students), researchers will necessarily have to deal with the ontologies of the theories, questions, and datasets available. Ontologies provide one mechanism for defining terms and their relationships, as suggested by the students. Searching for existing relationships among existing hypotheses and theories will inevitably create more unified and generalizable (the students' questions 3 and 4) data, conclusions, and – ultimately – theory.

Perhaps the most important insight provided in this article is the nuance that the guiding questions come before research design and implementation. I have seen many, many instances of researchers searching for theoretical linkages to interesting and important datasets *after* the data have been collected. Rarely, if ever, would such an approach result in any major theoretical breakthroughs. Putting the data before the theoretical drivers is tantamount to "putting the cart before the horse" and will surely lead to little or no theoretical or even corrective improvements. I applaud Prather *et al.*'s suggestions and hope that the general ecological community contemplates and utilizes their approach.

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WebPanel 1. Additional suggested literature in ecological theory

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