Research Article

Exemplification in Science Instruction: Teaching and Learning Through Examples

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Abstract: Although the practice of giving examples is central to the effective teaching and learning of science, it has been the object of little educational research. The present study attends to this issue by systematically examining the exemplification practices of a university professor and his students' learning experiences during a biology lecture on animal behavior. It is reported that the science instructor provided students with a series of procedural, conceptual, and analytical examples. Each type of exemplification was characterized by a unique focus, form and degree of dialogism. These examples promoted student acquisition of specialized scientific language and engagement in varied types of argumentation: inductive reasoning by parallel cases, inductive reasoning by causation, inductive generalization, and deductive reasoning. Furthermore, students' experiences learning from examples were contingent upon their performance of parallel instructional activities such as text reading and note-taking. Based on these findings, we argue for the importance of promoting student development of exemplification literacy (the ability to critically assess the use of examples in scientific communication) and the need for science instructors to provide students with opportunities not only to learn science concepts through examples but also to learn about the nature of scientific exemplification itself. © 2016 Wiley Periodicals, Inc. J Res Sci Teach 53: 737–767, 2016

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Giving examples is a practice central to the effective teaching of science. More than mere illustration of particular science concepts, exemplification is commonly used by science instructors for a variety of pedagogical ends, including developing and clarifying important concepts, explaining natural phenomena, giving supportive details to general and abstract ideas, engaging learners, and persuading students. D'Alessandro, Sorensen, Homoelle, and Hodun (2014) use *annotated examples* (worked examples wherein key physical concepts are fleshed out and applied) as a means to foster student reading comprehension of science texts. Dong (2013) provides English language learners with *culturally familiar examples* (teaching examples adapted to students' specific cultural backgrounds) to promote conceptual understanding as well as language acquisition. These varied pedagogical forms and functions of exemplification show how

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the communicative production and reception of examples can serve as a powerful learning tool when systematically and thoughtfully integrated into science classroom discourse.

Being given an example can influence one's social experiences and produce lasting cognitive and emotional effects on participants. As emphasized by communication scholars (Zillman, 1999; Zillman & Brosius, 2000), the experience of encountering a particular type of example can trigger cognitive processes such as the association of features to particular cases, recall of similar situations and priming of heuristics or mental constructs for interpreting larger phenomena. The exemplification experience can also be characterized by emotionality, particularly when the example given has a high degree of vividness such as the presentation of emotion-evoking imagery. Moreover, exemplification experiences can shape one's own judgements, beliefs and attitudes and hence constitute a potential source of perceptual bias depending on a multitude of factors such as presentational format, typicality, veridicality, representational accuracy, and frequency of occurrence (Busselle & Shrum, 2003). Such a possibility underscores the need to conceptually scrutinize how exemplification is approached in a science-teaching context as well as students' learning experiences.

Despite being one of the most familiar pedagogical resources for science teaching, how instructors teach through examples has received little attention from educational researchers. Likewise, science learners' experiences upon encountering certain types of science examples remain to be analytically examined. There clearly exists a need in the scholarly literature for naturalistic examination of the work of examples classroom instruction (Lee, 2004). The present study attends to this issue by means of an in-depth exploration of biological exemplification in post-secondary science instruction. More specifically, we systematically examine the pedagogical practice of example giving (instructor selection, oral deployment and student reception of instructional examples) during a biology lecture on animal behavior. Our research questions are as follows: (1) How is biological exemplification approached by a science instructor who sets out to teach biology through examples? (2) How do students experience learning from biological exemplification? In this study, exemplification is distinguished from *exemplarity* (Gelley, 1995), a term often used in reference to the practice of setting an exemplar wherein a speaker presents an ideal and singular instance of exemplary nature (i.e., a specific model with no parallel that is to be followed).

Theorizing Exemplification

It will be useful to begin by examining the etymological roots of the word *example*. Derived from the Latin words *eximere* (remove, extract, take) and *exemplum* (sample, specimen, or model), the term *example* refers to "a part taken out to show the character of the whole." As suggested by its literal meaning ("extracted sample"), exemplification can be considered a process analogous to the sampling of a larger pool of events or entities (Zillman, 1999; Zillman & Brosius, 2000). To exemplify is to select a single instance with a certain degree of similarity (shared features) with a group of other instances. A particular instantiation (the exemplum) is singled out to represent a larger group or category (the exemplified). As such, examples can shape our perception of phenomena, particularly when the exemplum is a concrete manifestation of an unobservable abstraction. In this case, imprecise or biased selection of examples can lead to distorted views and misinterpretation of the exemplified concept.

We conceive of *exemplification* as a communicative process in which a speaker discursively performs the act of giving an example by referring to a particular object, being or situation as an illustrative manifestation of a generality (concept or principle). A defining feature of such exemplifying act is "translatability between generality and particularity" (Harvey, 2002). Typically, prefaced by discourse markers (*for example*, *for instance*, *a case in point*), the act of giving an example invariably entails passage from particular to general or vice versa. Furthermore, the communicative process whereby an example enters classroom discourse can be conceived in terms of a metaphoric landscape or structured space (Watson & Mason, 2005). As shown on Figure 1, when giving an example, the science instructor selects an exemplum (a representative instantiation of a concept) that can be located along a continuum ranging from more to less familiar (represented by different shades of grey) depending on students' previous learning experiences. Underneath this horizontal landscape of familiar examples is the exemplified concept or generality for which the exemplum stands (symbolized by the dotted arrow). The exemplum is then communicated from instructor to the students and/or discussed in the classroom dialog (symbolized by the vertical solid arrow). The science instructor's choice of a particular exemplum can help shape students' learning experiences by triggering socio-cognitive and emotive processes, including association, recall, retrieval, engagement, frustration, etc.

In the specific context of the biology lectures on animal behavior examined in this study, the instructor selects and shares *exempla of nonhuman conduct*—concrete manifestations of abstract behavioral concepts such as territoriality and aggression. These examples relate behavioral observations and events witnessed by absent others (scientists' previous encounters with animals) and typically beyond students' immediate and direct experiences. As substitutes for personal perception and direct experience, these examples provide students with indirect encounters with animal behaviors that are mediated by curricular representations (texts, images, videos etc.). As such, biological exemplification is designed to influence students' impression and judgement of the behaviors of animals they may have never encountered before. Through the illustrative representations given to them, students are expected to learn how to assess the nature of the behaviors of animals like experts in the field do (i.e., produce expert interpretations of animal conduct, through processes such as the proposal of hypotheses and predictions and the analysis of

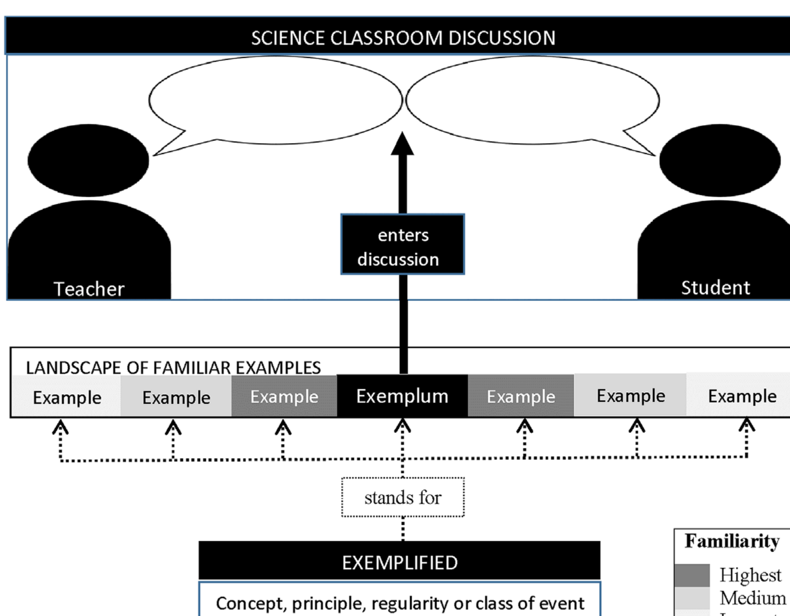


Figure 1. Exemplum (representative example) being selected from metaphoric landscape and entering classroom discussion.

data). Therefore, the examples given by the instructor also serves to induct students into the exemplification practices of professional biologists. By means of their exemplification experiences, students are exposed to the communicative norms of giving examples in this particular scientific field (i.e., presentational formats and approaches favored by scientists).

Examples are given for varied communicative purposes depending on contextual factors such as the participants' roles, interactional setting and channel of communication. This is noted by Clouse (2010), who emphasizes that exemplification can serve different communicative functions, including illustrative (to clarify a point), rhetorical (to make persuasive arguments), and engaging (to arouse interest) ones. In published research articles, examples have been shown to have the rhetorical function of supporting scientific explanations. Kanoksilapatham (2005) identifies exemplifying as a rhetorical move frequently used by biochemists in the discussion section of their published articles to convince readers that their research efforts were indeed successful and to consolidate their results. Hyland (2007) describes how scientists and engineers frequently give examples that are marked (prefaced by the expressions such as, for example, e.g., like, for instance, say) and unhedged (devoid of tentative expressions such as *to a certain extent*, *maybe*). These examples not only add clarity by supplying a particular instance of a generality and disrupting abstract passages with concrete references but also provide rhetorical support for the scientific arguments and claims made (i.e., carry persuasive weight). As such exemplification serves important epistemic functions in scientists' written negotiation of meanings.

Our theoretical stance takes into account intra-example features (the design and structure of individual examples) as well as inter-example features (the sequencing and arrangement of examples in instruction). For us, successfully teaching a science concept is not simply a matter of providing students with the ideal or perfect example, but rather it is involves combined deployment of multiple examples in ways that can support an inductive formation of concepts by students (Parker, 2011; Taba, Durkin, Fraenkel, & McNaughton, 1971). Students may, therefore, develop deep conceptual learning by studying a small set of examples under the guidance of a science instructor. As such, instructional effectiveness of examples is contingent upon internal factors such as clear and coherent integration of multiple modalities of information (texts, diagrams, and aural presentation) as well as external factors such as the number of examples given and their intermingling with other instructional modes (practice problems, lectures, etc.; Atkinson, Derry, Renkl, & Wortham, 2000). Effective exemplification requires examples to be given in an order that is consistent with one's communicative purposes (Brandon & Brandon, 2013; Clouse, 2010). Depending on whether one is seeking to persuade others (e.g., provide support for a point), explain a general point (i.e., provide clarification on a generality), entertain others (i.e., keep readers/hearers interested and engaged) or attract attention, a sequence of examples can be arranged progressively (from the least to the most compelling), chronologically (from past to present), by complexity (from simple to complex), or by degree of vividness (least to most vivid).

Example-Based Instruction and Learning

We now review the two main areas of research related to instructional examples: naturalistic studies of exemplification in classroom discussions and psychological studies of student learning from worked examples.

Exemplification in Classroom Discussions

Previous naturalistic studies have revealed a wide range of variability in the pedagogical use of exemplification in classroom interaction. Both instructors and learners have been shown to resort to different types of examples with varied duration (ranging from single utterances to longer interactional sequences), communicative form (oral, written, visual) and instructional format (exam questions, drawing assignments). One particular type of example that has been previously documented is participant example. Oliveira (2011) describes how many elementary teachers provide *participant examples*—oral descriptions of actual or hypothetical situations wherein the teacher presents herself and/or her students as characters to illustrate topics under discussion. Meant to illustrate the ideas under discussion, participant examples help humanize impersonal aspects of science curricula. Furthermore, the specific ways in which students are referred to in these personalized examples may have the social effect of positioning students in particular ways in relation to the teacher and science (i.e., creates a social structure). Likewise, Wortham (1992) describes how certain teachers may acquire a higher social status in relation to their minority students by giving participant examples wherein teachers play powerful characters while students are assigned subordinates roles. These studies highlight how participant examples can produce a variety of effects ranging from humanizing the topic instruction to reinforcing differences in status (i.e., foster unequal social structures).

Examples also provide biology teachers with a powerful device for facilitating controversial discussions. Oliveira, Cook, and Buck (2011) describe how a teacher resorts to the provision of humorous examples ("Can a Dalmatian have a baby with an alligator?") to foster a less tense classroom atmosphere for the discussion of the sensitive topics such as animal reproduction and macro-evolution. Goldston and Kyzer (2009) note that biology teachers often resort to examples of lower animals and plants when teaching evolution to avoid offending students who may hold religious objections to the concept of human evolution. These studies reveal the importance of strategic selection of examples to teachers' approach to controversial science instruction.

Others have used examples to contextualize the explicit nature of science instruction and to support student development of more sophisticated views of the scientific endeavor and of the scientists themselves (Clough & Olson, 2004). McComas (2008) underscores the largely untapped potential of *historical examples* (historical instances, cases, or narratives about scientific discoveries) as a means to strategically help students and the general public better understand abstract aspects of science (epistemic and sociological generalities) such as tentativeness, subjectivity, creativity and empiricism. Doing so requires historical as well as contemporary examples that are authentic, specific, inter-disciplinary and expand the learning experience beyond mere instances of lab experimentations.

Like science educators, mathematics teachers have also been shown to deploy a wide variety of instructional examples. Michener (1978) distinguishes among different types of examples by their use in the teaching and learning of mathematics: (i) *start-up examples*—used when a new theory or concept is first encountered; (ii) *reference examples*—standard cases that are widely applicable and can be linked to several concepts and results (possible source for counter-examples); (iii) *model examples* – generic cases that summarize expectations and assumptions about concept; and (iv) *counterexamples*—examples that show that a conjecture is false; intended to sharpen distinctions between concepts and demonstrate the limits to the universality of results. Several additional types of examples are identified by Watson and Mason (2005) also for mathematics education: (i) *non-examples*—cases that demonstrate the boundaries or necessary conditions of a concept; (ii) *extreme examples*—boundary examples, in the sense of being more of an unusual instance than a representative/generic case; and (iii) *classic examples*—passed down from generation to generation; generic illustrations that foster dominant images. Emphasized in the literature is that good examples are generative rather than figural—they effectively generate new understandings rather than simply illustrate concepts.

Consistent with the above research, exemplification is widely advocated in the practitioner literature. Many science teaching methods books encourage teachers to articulate instructional objectives and oral questions with action verbs such as "provide an example" (Chiappetta & Koballa, 2002) and "illustrate" (Bybee, Powell, & Trowbrige, 2008). Giving examples is advocated as a practice essential for teachers to promote student learning beyond mere recall of factual knowledge and to scaffold higher levels of student cognition. Lederman, Lederman, and Bell (2004) state that "another type of comprehension-level objective would be to have students provide an example ... students must demonstrate their understanding of the concept to accomplish this task" (p. 88). However, such endorsement is made without any explicit definition or nuanced distinction among specific types of exemplification.

Learning From Worked Examples

The instructional effectiveness of examples has also been the object of considerable research in the field of educational psychology. However, educational psychologists have favored a decontextualized approach focused mainly on formal cognitive attributes of examples rather than practical enactment in real-time classroom discourse (Lee, 2004). In this research tradition, examples are conceived in terms of particular cognitive operations and assessed based on their perceived "match" to the particular target concept they represent without consideration of the local context of interaction. Learning involves mastering the structural nature of a target concept (mathematical formula, physical concept, etc.) and is accomplished through the comparative study of multiple *worked examples* (Atkinson et al., 2000; van Gog, Paas, & Sweller, 2010) that provide students with step-by-step guidance on how to solve a particular type of problem. Provision of procedural steps to be taken is meant to reduce the cognitive load that students often experience when learning through traditional problem-solving pedagogical methods (Kalyuga, Chandler, Tuovinen, & Sweller, 2001; Sweller, van Merrienboer, & Paas, 1998).

Informed by cognitive load theory (Sweller, 2010), much of this research is concerned with the prevention of cognitive overload (excessively high mental load) and promotion of germane load (optimized working memory load) among novice learners engaged in cognitively complex tasks (problems). Doing so involves strategically designing cognitive tutoring systems with worked examples that provide learners with instructional guidance or assistance in the form of a written worked-out solution procedure, or a computer animation showing the steps required to solve a problem—*animated examples* (Wouters, Paas, & Van Merriënboer, 2008). Worked examples have been shown to be effective in reducing learner's acquisition time (Van Loon-Hillen, van Gog, & Brand-Gruvel, 2010) and mental effort particularly when presented in a segmented format—as a procedure divided into pieces separated by blank lines (Spanjers, van Gog, & Van Merriënboer, 2012).

In sum, the above literature provides initial evidence that a wide variety of examples can be found in science classroom settings. However, theorizing and problematizing of the pedagogical value and epistemic role of examples in science instruction is clearly limited, thus suggesting reliance on tacit understanding. As Zillman (1999) writes, "everybody is familiar with examples. Everybody has been given examples ... everybody therefore, has some tacit understanding of a relationship between an example and a larger entity to be exemplified by it" (p.72). Moving beyond tacit deployment and achieving more sophisticated, theory-based understandings is precisely what we set out to accomplish by examining how exemplification is approached by a biology instructor and experienced by learners.

Methodology

This exploratory paper relies mainly on descriptive data (video-recordings, surveys, and interviews), which are analyzed inductively to build a naturalistic (Lincoln & Guba, 1985) account of a university biology professor's exemplification practices during course instruction. Such a methodological approach allowed us to conduct an in-depth exploration of students' experiences learning from scientific examples without interfering with the biology instructor's existing practices.

Participants

Participants in this study included a group of undergraduate students enrolled in a 3rd-year course entitled *Animal Behaviour* in the fall semester of 2014. With a total enrollment of 75 students, the majority of this population was in their early twenties, of White ethnicity and mainly of Anglophone origin with a minority of Franco-Ontarians. A few other minority students were from Middle Eastern or North African origin. There were also students of other nationalities: one Dutch, one South African, and one Jamaican. The course was taught by the second author (henceforth referred to as Adam) who held a Ph.D. degree in biology (Pollination Ecology) and had approximately 12 years of teaching experience (lecturing) at the university level.

Aimed at introducing students majoring in biology to the scientific study of animal behavior, the course focused primarily on the ecological and evolutionary benefits (i.e., adaptive value) of a variety of animal and human behaviors such as communication, altruism and sociality, territoriality, aggression, feeding habits, mating systems, and parental care. The course included *lectures* (two weekly whole-class sessions of 1.5 hours) as well as *discussion groups*—one weekly small-group session of 1.5 hours in which students watched videos (nature documentaries) and discussed manuscripts from the primary literature (seminal research articles). During the lectures, Adam typically used PowerPoint slideshows to engage students in the discussion of examples of animal behavior drawn from the textbook *Animal Behavior* (Alcock, 2013). Using jpeg images from the instructor's package, Adam incorporated images (figures, graphs, etc.) exactly as they appeared in the textbook itself. The use of the same imagery as in the textbook was meant to allow students to better integrate the explanations of the examples with the more in-depth information taken from their readings of the textbook. Adam described his example-based teaching approach as follows:

> I teach using examples because they illustrate *how and why animals* behave but I emphasize that the students are meant to understand what these examples tell us about *the fundamental causes and consequences* of the reason why animals behave this way. . .I feel it is absolutely essential for them to be able to develop this ability to effectively communicate the *fundamentals of the theories and principles* of Animal Behaviour, as opposed to reiterating and regurgitating facts based on specific animal examples.

As italicized above, Adam's deployment of exemplification served descriptive as well as explanatory purposes ("how and why"). The examples he gave were meant to not only illustrate by referring to particular manifestations of general behaviors prevalent across individuals and species but also to support student inductive construction of generalities central to the field ("the fundamentals of the theories and principles of Animal Behaviour"). Adam identified the following as the main instructional goals behind his exemplification practices:

> My main pedagogical focus is on the training of students to be able to use examples to *determine the generalities* of the underlying theories. This has two main goals: firstly *to make the course more engaging and interesting to the students*, rather than focusing on text and theory, we go to explore actual animal behaviors and arrive at the theoretical aspect by deduction/induction. Secondly, it would hopefully provide the students with a *learning scaffold* that would allow them to figure out the ecological and evolutionary significance/ role of an observed behavior upon viewing it for the first time on their own. Therefore, the

> second goal is meant to create an ability to transfer their learning from the class to new, unforeseen circumstances in the future.

Adam's adoption of exemplifying practices aimed at fostering student engagement is consistent with previous efforts to make classroom interaction more engaging through the use of *interesting examples* (Shimoda, 1993). On the other hand, Adam's second instructional goal of scaffolding student learning and promoting cognitive transfer is aligned with educational psychologists' search for worked examples that best represent a target concept (Sweller & Cooper, 1985). As such, Adam articulates a relatively balanced teaching philosophy that combines both discursive and cognitive perspectives on exemplification.

Although Adam considers exemplification to constitute a powerful pedagogical tool, he discourages students from using examples themselves, particularly when answering questions in the course examinations (midterm and final). This was particularly evident in the evaluation section of his course syllabus where students were told: "you will be expected to explain the fundamental underlying theories and principles of this study without needing to rely on examples." He explained this practice as follows:

> The reasoning behind why I do not accept examples as explanations in the test answers for why animals behave the way they do, is because a) *they only illustrate* and do not necessarily EXPLAIN and b) usually *examples are exclusive* to one group of animal and do not encompass ALL SITUTATIONS that should be covered by an explanation of general theories or principles.

Adam's goal of teaching by example was to provide students with a cognitive tool for discerning the general principle underlying the given example. He emphasized to students (both at the beginning of term and throughout) the need to focus on the deduced adaptive function of each behavior by vocally stating the "take-home message" for each example. Furthermore, Adam's practices did not include unplanned exemplification (in-the-moment generation of examples). Adam planned the presentational format and delivery of all the examples well in advance based on careful consideration of the curriculum and his educational objectives.

Data Collection

To provide an account of example-based teaching practices (Research Question 1), we video-recorded a total of 13 lectures during the second half of the fall semester (October–December). Video-recordings were made in a classroom equipped with *Echo360 Active Learning Platform* (Echo360, 2015), a computer system of lecture capture that can be used to digitally record an instructor on a podium, as well as materials displayed through the projector (e.g., PowerPoint slides). This data collection resulted in a body of nearly 20 hours of videos focused mainly on the teacher who wore a lapel microphone. Though centered on the instructor's actions, the wide-angle ceiling camera in the back of the room and a high-sensitive microphone enabled us to also capture student comments, which were also deliberately repeated aloud by the instructor. All video-recordings were transcribed in full (see Appendix for transcription conventions) and their contents examined to explore how biological exemplification was pedagogically approached.

Consistent with our exploratory goal of achieving a more sophisticated understanding of a real-life phenomenon, we resorted to a qualitative methodology that favored analytical depth over breadth. Rather than attempting to quantify the recurrence of exemplification across our entire video dataset, we limited the scope of our up-close examination of pedagogical and experiential processes during a single event, a lecture wherein representative exemplification practices (that also recurred in other lectures) stood out as being particularly effective, as experienced by the participants themselves. Because effective examples had already been shown to foster memorable experiences as well as increased retention and retrieval of exchanged information (Busselle & Shrum, 2003), we asked our participants to identify an example given at any point of the semester that they remembered particularly well (item 5 on Table 1 below). Recurrent participant identification of territoriality-based examples given during the lecture on habitat use by animals led to its selection as the analytical focus of the present study.

With a format similar to a *concept formation lesson* (Parker, 1988) wherein students engage deeply with multiple examples, the lecture focused specifically on the biological benefits and costs associated with being either a resident holder or a challenging intruder of a territory. Teacher-guided engagement with examples served as a scaffold for students to form (co-construct) the concept of animal territoriality. Adam began the session with the following comment "[Today] we are going to look at a number of animals that hold territories and defend them against others and see if there is a difference between those that are resident-holders and resident-challengers or intruders." This statement was then followed by whole-group discussion of a series of examples involving the territorial behaviors of several different species. Overall, a total of seven examples were given during a time span of 89 minutes. With variable duration, these examples focused on the territorial behaviors of different animals (birds, butterflies, damselflies, fiddler crabs, tarantula wasps, and poplar aphids). The three examples examined in this study engendered particularly long discussions, with nearly a third of the lecture time being devoted to their discussion.

Data on students' experiences learning from biological exemplification (Question 2) originated from various sources, including individual surveys, focus group interviews and written artifacts. At the end of the course, students were asked to anonymously fill out a survey with a series of open-ended questions that prompted them to articulate their experiences learning from examples during the semester (see Table 1). Subsequent to completing this survey, volunteer students participated in a focus group interview during the last discussion group session of the course. Focus group (or small-group) interviews were selected to provide students with a socially oriented arena wherein to share their ideas and beliefs regarding the pedagogical use of examples in the company of people who had similar learning experiences and also to encourage students to reflect on the ideas of others as well as their own. The focus groups were led by the course Teacher's Assistants and the professor was not present, in order to eliminate any sentiment of pressure on the students with respect to their analysis of the course and its instruction. Typically deployed in educational research to help interpret the results of a survey (Bernard, 2002), the focus group method has been shown to be effective in stimulating thoughtful talk among participants and in revealing a range of views or perspectives on a particular topic or experience (Bogdan & Biklen, 2003). Our semi-structured interview protocol was composed of the seven open-ended questions from the exemplification questionnaire. This afforded us opportunities to probe further into their students' experiences by posing clarification questions and asking students to elaborate on the reasons behind their written responses. Lastly, we also collected written artifacts such as students' notes taken during lectures as well as samples of answers from their course examinations. When asked about their use of learning strategies such as taking notes during class (items 6 on Table 1), several students volunteered to share copies of the notes taken during the semester with the researchers. These served as a secondary data source that served as a complement to student self-reported data.

Data Analysis

Our analytical approach is grounded in the tradition of naturalistic studies of classroom discourse (Erickson, 1996; Saville-Troike, 2003; Schiffrin, 1996). This qualitative research tradition is concerned primarily with the systematic and in-depth examination

Table 1
Exemplification questionnaire

Item	Prompt
1	Please describe your approach in the process of learning the principle behind an example of an animal behavior in class (Do you analyze diagrams/figures/data?)
2	What do you do when the instructor is explaining the examples? (Do you write everything you can? Do you try to generalize the concept?)
3	What kind of notes do you take in class on a given example of an animal behavior?
4	Do you normally read the textbook chapters before coming to class or is the classroom lecture the first time you encounter each of the specific examples?
5	What was an example that you remember particularly well or really enjoyed? Please explain why
6	Do you use a similar or different process when you are studying the material outside of class as you do when taking notes during class? Please explain
7	Please describe what strategies you use to describe a principle of animal behavior without relying on the use of examples

of naturalistic meaning-making processes underlying linguistic exchanges in classroom settings. Its main theoretical assumptions are that learning is linguistically mediated and entails sociocultural construction of meanings through semiotic exchanges, such as discussions, writing, and picture sharing. Unlike cognitively oriented research concerned primarily with the conceptual schemes (i.e., issues of conceptualization), it focuses primarily on minute contextual details of the learning situation such as *modality* (modes of communication deployed by speakers when accomplishing their daily and routine work) as well as *positionality* (how the interacting participants position themselves in relation to each other and outside groups or individuals).

Our analytical goal is not simply to identify a direct causality between a cognitive outcome (student learning) and a particular discursive practice (a type of teacher example). Such a goal would be inconsistent with the complex and fluid nature of language. Furthermore, we consider a focus on direct causality problematic in the sense that it would presume the existence of a deterministic relationship between language and thought. As recent research has shown, although our ways of speaking can influence our ways of conceptualizing (Boroditsky, 2001; Gentner, Imai, & Boroditsky, 2002), spoken language does not determine human thought (i.e., does not dictate how we think). Rather than embracing linguistic determinism, our analysis is based on the premise that a variety of contextual factors also need to be taken into account when examining the impact of a particular teacher example on student cognitive engagement. The exemplifying reference by itself cannot guarantee a particular learning outcome.

Central to our discursive characterization of exemplification practices (Question 1) are two defining attributes, namely focus and dialogism. *Focus* is fundamentally what an example is about, that is, the specific type of meanings and knowledge it involves. As revealed by previous sociological studies of knowledge building in classroom settings, teaching practices can encompass context-independent meanings (i.e., focus primarily on specialized abstractions and general principles) or context-dependent meanings (i.e., focus mainly on the particularities of a localized and concrete context; Bernstein, 1971; Dowling, 1998). Furthermore, pedagogical activity can be about procedural knowledge (science processes: research procedures and methods) or declarative knowledge (science products: concepts and principles). Application of these theoretical distinctions to our transcribed data led to an emergent typology of exemplification. More specifically, distinctions were made among three different types of examples, each with a distinct epistemic focus: procedural examples (focused on procedural knowledge), conceptual examples (focused localized and situated declarative meanings) and analytical examples (focused on generalized and decontextualized declarative meanings).

In contrast, *dialogism* is a theoretical notion concerned mainly with students' discursive performance, that is, their level of participation in whole-class discussion and the impact of their oral contributions has on shaping the course of the discursive exchange. When dialogism is high, discourse is characterized by more active participation of students in oral meaning making. On the other hand, when dialogism is low, discourse tends to be more monologic (i.e., expository instructor monologues with reduced student vocalizations).

Our discourse analysis entailed in-depth examination of *key cultural scenes* or *communicative episodes* (Saville-Troike, 2003); that is, short stretches of naturally occurring discursive interactions with variable numbers of utterances. We identified moments in the lecture session in which the teacher and students turned their attention to instantiations or manifestations of territorial behaviors in the animal kingdom; that is, biological situations involving instances of combat engagement and aggression against peers. The defining feature of these scenes was a divergent referential shift in focus from the particular to the general. Prefaced by markers of exemplification (*for example*, *another example*), these scenes typically began with descriptive reference (verbal and visual) to a particular species of animal whose territorial behavior had been scientifically studied and then gradually shifted to larger empirical trends as more general biological principals were collaboratively constructed or derived through discussion.

Our discursive analysis had a dual focus that took into account both the social and rhetorical work of biological examples. Social work refers to the interpersonal functions served by each example such as participants' interactional positioning in relation to each other, animals and science. In contrast, rhetorical work is concerned with the specific argumentative functions served by each example. Informed by previous theoretical work on reasoning (Copi & Cohen, 2007; Toulmin, 1958), we sought to identify the specific rhetorical purpose served by biological examples (inductive or deductive) as well as logical components in participants' speech and imagery: *data* (the premises for a particular conclusion such as a graph showing the findings of particular research study), *claim* (the conclusion considered to logically follow from the data), and *qualifier* (specifications of conditions under which the claim can be confirmed to be applicable or otherwise, to be overturned).

Exemplification discourse is not only accomplished but also experienced by speakers in particular ways. Our participants' experiences of learning through examples (Question 2) were examined through an analytical qualitative approach that incorporated elements of grounded theory (Glaser & Strauss, 1967). This approach called for the iterative and combined use of interpretative and flexible methods of analysis such as close reading, open coding, and memo taking (Bernard, 2002; Emerson, Fretz, & Shaw, 1995). Given the lack of prior research in this area, there were no *a priori* hypotheses or codes. Instead, themes were allowed to analytically emerge and were gradually refined based on close examination of meanings and patterns across the transcribed data. Our analytical focus was on providing a phenomenological account of participants' classroom experiences in a class strategically designed to promote science learning through dialogic citation of examples. More than simply examining students' impressions of the class, we sought to better understand cognitive and social aspects of students' experiences upon encountering biological examples based on our own observations and students' self-reports.

Investigating participants' own judgments helped improve the credibility of this study by ensuring that our analysis constituted an accurate representation of their learning experiences (Clandinin & Connelly, 2000). Furthermore, the use of multiple rich data sources allowed for triangulation and helped enhance the validity our findings (Creswell, 2007; Patton, 2002). By comparing video, interview, and survey data, we sought to create analytical consistency and provide a trustworthy account of the phenomenon at hand. More specifically, our video-recorded observations were compared to students' written artifacts and self-reports in terms of their evidence of processing (student engagement and meaning-making fostered by specific examples) and acquisition (learning that resulted from specific examples). Consistency of patterns across data sources was considered indicative of analytical validity.

Results

Our findings are now reported. To answer our research question 1 (how is biological exemplification approached by a science instructor?), we first describe the types of examples by the instructor. Attention is then given to students' self-reported accounts of their experiences learning through biological examples (question 2).

Teaching Through Examples

Overall. The main trend in our data was the instructional deployment of three distinct types of biological exemplification with varying levels of dialogism. Throughout the lecture, Adam provided students with a series of procedural, conceptual, and analytical examples of animal territoriality. As shown on Table 2, each type of example was characterized by a unique focus, form, function, and frequency of student interjections.

At the level of scientific argumentation, the series of biological examples given in this session was consistent with a rhetorical pattern known as *inductive reasoning by parallel cases* (Monahan, 2015) in the sense that a scientific argument was ultimately made in favor of a larger generalization (claim) based on a fundamental similarity across multiple dissimilar instances (data). Together, the various examples of animal territoriality fundamentally served as empirical grounds or premises for the more general conclusion that territoriality has resource-holding power (i.e., a

Table 2
Types of exemplification

	Procedural exemplification	Conceptual exemplification	Analytical exemplification
Focus	Research design; Experimental approaches	Application of biological principles; Convergent: general to specific	Derivation of biological concepts and principles; Convergent: general to specific
Form	Abstract representations (schematics, drawings)	Realistic pictures, videos	Pictures and graphs
Function	Introduction to methods; Methodological evaluation; Generation of methodological understanding	Explaining observations; Entertaining hypotheses; Posing research questions; Generation of conceptual understanding	Evidence-based claiming; Scientific argumentation; Generation of analytical understandings
Discussion duration (minutes)	7	9	13
# of student interjections	1	4	9
Frequency of student interjections	1 comment every 7 minutes	1 comment every 2.25 minutes	1 comment every 1.50 minutes

self-reinforcing cycle based on causes and consequences of fitness that afford some individuals a greater ability to claim and hold a territory, as well as the superior advantage of a greater access to resources that results) regardless of individual species. More than mere illustration of standard concepts in behavioral biology, Adam's biological examples performed the rhetorical work of persuading an audience of science students that being a resident holder is generally advantageous to animals (an empirically grounded conclusion). This rhetorical work is visually displayed in Figure 2 below.

Procedural Exemplification. A defining feature of this type of exemplification was its focus on the methodological dimension of behavioral biology research. Centered on abstract pictorial depictions (e.g., schematics and drawings) of procedural particularities or generalities (e.g., standard research methods), these examples were used for the purpose of generating methodological understandings. This was observed early in the lecture, when Adam shared a slide with a diagrammatic representation of the procedural design used by early studies of butterfly combat. Its discussion lasted for approximately 7 minutes (Fig. 3):

> Adam: Here is an example of how *they* kind of started looking into these [territoriality contests] using these butterfly combats. . .It turns out that part of *this study might have been flawed* . . . catching the white butterfly could have caused it stress, or damage, or impacted in some way its condition so that it is not as capable of winning a second combat upon re-release due to the fact that it was just kept in a net off to the side, it might have been flapping around the whole time, so a slight modification was made . . . the modification was that *they* removed the resident butterfly and instead of leaving him off to the side in a net for him to flap around for a half an hour, you put them in a dark cooler . . . for insects which are exothermic animals, being put into a cool environment just kind of slows them down and is *a standardized method* to calm down and to keep an insect off to the side for a while without causing it any stress or damage.

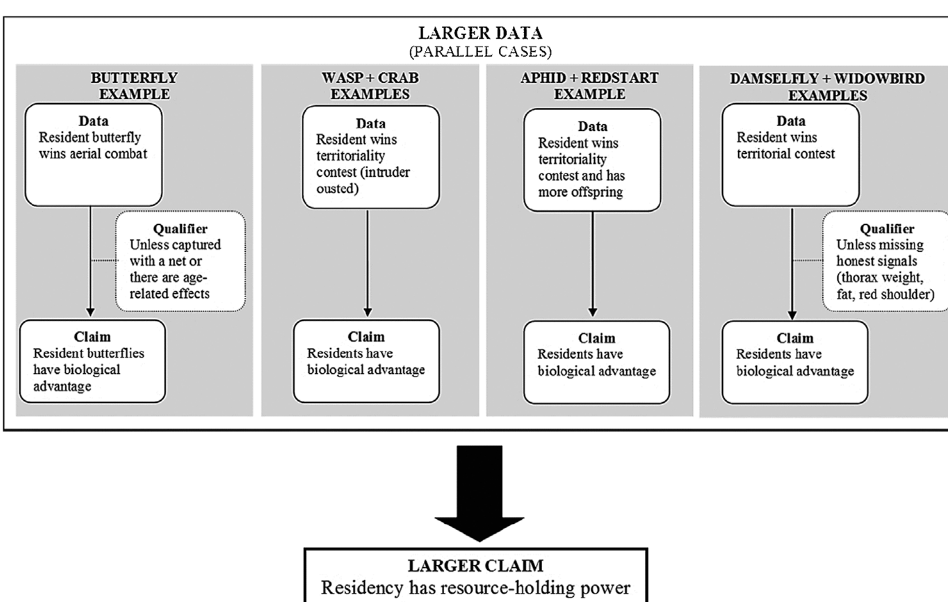


Figure 2. Rhetorical work of biological exemplification.

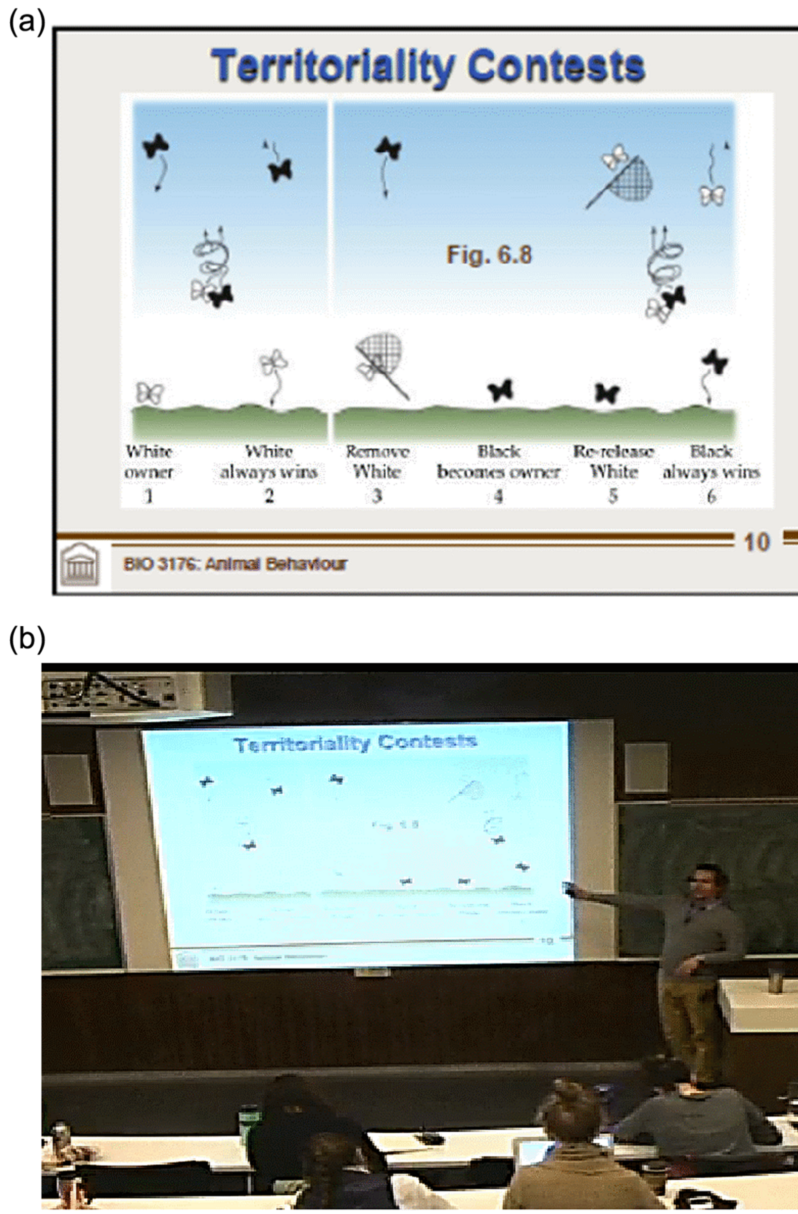


Figure 3. (**a**) Slide of butterfly experiment and (**b**) instructor presenting slide to class. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Rather than providing a methodological exemplar (an ideal model to be followed), Adam brings attention to a "flawed" experimental approach previously used by behavioral biologists to research territorial behaviors among butterflies, namely "leaving him off to the side in a net." By providing a *bad example* (Gelley, 1995) of a research procedure rather than the standard method of placing insects in a dark cooler, Adam strategically engages students in methodological evaluation (critical appraisal of alternative procedures). Provision of this "bad" example illustrates how not to design field experiments that involve capture and release of insects (i.e., an approach that should be avoided). As such, this "non-example" of good research can be said to serve as a springboard for the generation of methodological understandings.

Methodological exemplification was characterized by having had the lowest levels of dialogism. In addition to being mostly monologic (only one student interjection throughout the entire exchange), the example is articulated predominantly in the third person (*they* = scientists that conducted the study). As such, students are positioned as novices observing the work of expert biologists in the field. Furthermore, even though the scientists conducting the butterfly combat experiment are the primary focus of this example, they are not pictorially depicted on Adam's slide which is completely devoid of actual human presence (flying nets are used to symbolically represent human agency). This example is primarily an instantiation of scientists' behaviors (their research methods). Butterflies' territorial behaviors constitute a secondary manifestation tangential to what is being exemplified.

In terms of its rhetorical structure, the above procedural example entails *inductive reasoning by causation* (Monahan, 2015). In this rhetorical pattern, observation of specific experimental conditions is used to draw a causal inference, that is, to infer a general causal relationship or connection between two events: a cause (the capture of resident butterflies with a net) and an effect (the resident butterflies' unexpected loss of territorial combat upon release). Premises about specific experimental conditions are used to draw the general conclusion that nets in general produce inadvertent effects on capture/release experiments with animals (butterflies and others) and that careful measures must be taken to avoid the so-called "cage effect" in research methodologies and experimental design.

Conceptual Exemplification. Focused on realistic representations (videos and photographs) of organisms, conceptual exemplification entailed application of a generalized principle or concept to a specific biological situation (i.e., a shift from general to particular) and generation of conceptual understandings. This convergent mode of exemplification was deployed by the instructor for several distinct epistemic purposes, including co-construction of scientific explanations for particular cases, collaborative entertainment of hypotheses and collective posing of research questions. It was observed halfway into the session, when Adam showed a slide with the photograph of a tarantula wasp and orally described its territorial behavior. Its introduction led to a 9-minute discursive exchange (Fig. 4):

> Adam: These *tarantula wasps* defend territories quite vigorously against other *intruding males* and *their* territory is determined by some kind of visual assessment of an area that contains presumably some good amount of food resources for *them* to be able to prey upon and *they* perch themselves on the top of shrubs or small trees in order to patrol *their* territory and if there is a male that comes in to *their* territory, well, unsurprisingly, *they* engage in these aggressive combats and intruders typically are ousted, so *they* end up being chased away and the resident manages to reclaim their territory ... *again there is a notion of a resource-holding power.*

As can be seen above, Adam introduces the wasp example by showing students what this particular organism looks like while orally describing its territorial behavior. No written information about the methodological design of experiments previously performed with wasps is actually included on the slide, an indication that methodology is secondary to this particular example. More importantly, Adam invariably makes plural references ("tarantula wasps," "intruding males") and third-person pronouns ("they," "them," "their") positioning himself as an external observer (a professional biologist). No mention is actually made of the individual wasp being portrayed on the picture. Instead, patrolling and aggressive combats are presented as territorial behaviors shared by

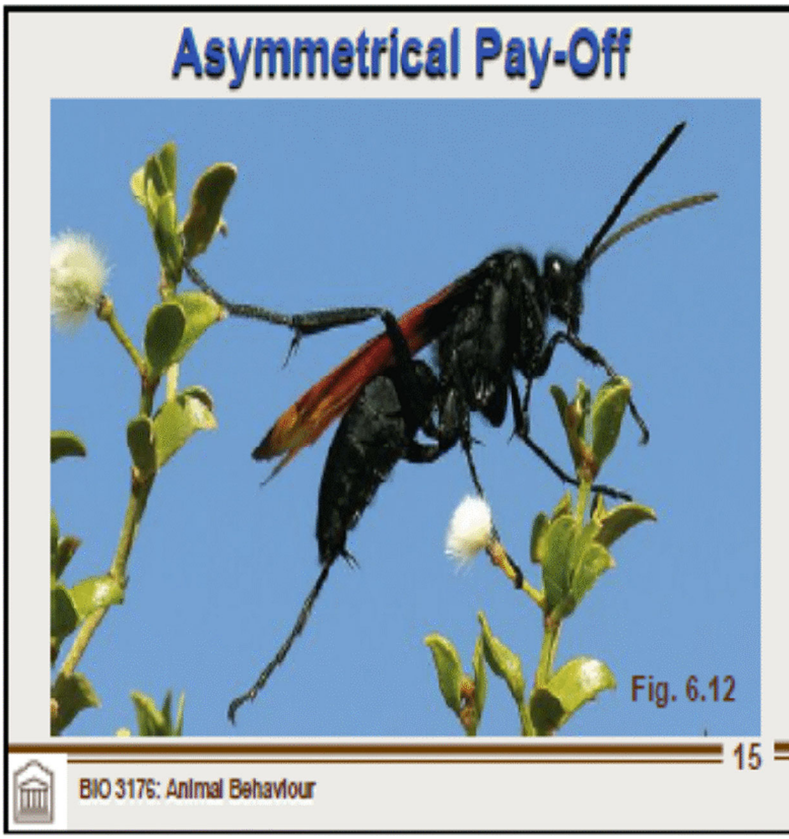


Figure 4. Slide of tarantula wasp. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

tarantula wasps in general (i.e., the entire species). In doing so, Adam offers a *model example* (Michener, 1978), a generic case that summarizes expectations and assumptions about the concept of "resource-holding power" of territorial behavior, namely that residents are typically victorious in combats with intruding males. By presenting, resident wasps' victory as another instantiation or manifestation of the previously learned concept of "asymmetrical pay-off" (the generalized notion that resident animals have more to lose in territorial battles due to the amount of time/energy that they have already invested in claiming and defending it, depending on how long they had previously been the territory's resident), Adam moves from the general to the particular.

> Subsequently to naming the concept under exemplification, Adam orally described the findings of a previous scientific experiment with tarantula wasps:
>
> Adam: If the original resident is removed from the territory, put away in a cooler for a longer period of time, meaning a new intruder comes in and says *hey, this is a good territory, I'll take this one and* sets up shop and starts defending it against others, when that original resident is re-released after some significantly extended period of time like an hour or two . . . that previous resident is often incapable of taking it back again.

While continuing to show the same photograph, Adam orally shifts into a more involved mode of conceptual exemplification. Rather than maintaining a third-person position, he momentarily shifts into first-person perspective by uttering what a hypothetical wasp would have said upon intruding a resourceful territory: *hey, this is a good territory, I'll take this one*. His comment is prefaced with the reported speech marker "says" and there is noticeable shift in inflection or intonation, hence signaling to students that he is now uttering the words or thoughts of someone else (the intruding wasp), not his own. By using *I* in reference to an anthropomorphized tarantula wasp, Adam deploys ventriloquism (Bakhtin, 1986), momently speaking "through" the voice of a wasp. In doing so, he gives a *participant example* (Oliveira, 2011), an illustrative oral description of a hypothetical situation wherein the teacher presents himself as a character to illustrate the topic under discussion. This more personal account of wasp territoriality led a high degree of dialogism. Subsequent to the above participant example, monologic lecture gave away to a more open dialog wherein students interjected four times:

> Adam: So what we are talking about here is the amount of time that *you've held* a territory . . . so what's going on here? Let's answer it together. What is it about the amount of time that *you've been* a territory-holder that causes an individual to be more aggressive, to defend it more vigorously and to end up winning it back?
>
> Student: Those that had it longer [inaudible] and they must have won.
>
> Adam: Ok, yes, so if they have had it longer, they presumably have had more encounters with more individuals and presumably won them, so what does that mean to the resident in terms of costs and benefits?
>
> Student: Uh, I don't know if it has to do with their populations, like if it was during breeding season [inaudible] if they get out of their territory, they won't be able to maintain their population.
>
> Adam: Well, umm, we know that the benefits are, of holding a territory are that you have more mating opportunities, that *you have* resources to survive and for the offspring to survive, so the benefits are clear, I think . . . can we talk about it in terms of costs then? So, what are the costs of losing a territory that *you've had* for a short time versus losing a territory that *you've had* for a long time?
>
> Student: Having more to lose.
>
> Adam: Right, having more to lose can be another of saying that there is a bigger cost, so if *you have* had a territory for a longer period of time *you have* invested time, *you have* invested energy and effort.

Adam repeatedly used the singular *you* while reacting to students' oral contributions to the discussion about residency-time effects on wasp territoriality. It should be noted that his second-person pronouns do not actually refer to any particular student, as evident by the fact that they can be replaced by the indefinite *one*. Instead, Adam uses *you* generally to encourage students to take on the role of a hypothetical and somewhat anthropomorphized wasp reflectively considering the biological costs and benefits associated engaging in a combat with an intruder after varied periods of territory ownership. By enacting what such a fictional wasp might "say, think, or ask," Adam dialogically and rather informally models to his students an accepted way of making sense of animal behavior, namely a careful and systematic cost/benefit analysis.

Unlike the other two types of biological exemplification, conceptual examples involved a deductive type of reasoning wherein a rhetorical move is made from general premises to specific conclusions (Copi & Cohen, 2007). As seen in the above conceptual example, it did not entail derivation of principles from pattern recognition. Instead, the focus was on the application of known principles to biological situations that, though novel, were highly specific. Its main function was explanatory in the sense that it provides Adam and students an opportunity to collaboratively articulate a scientific explanation for animal behaviors that were consistent with the conceptual cannons of this scientific field.

Analytical Exemplification. The last type of exemplification centered on the analytical derivation of biological generalities from particular data sets reported by previous research studies. A defining feature of analytical exemplification was its invariably divergent nature (from the specific to the general). Combining realistic photographs alongside graphic representations of quantitative data, analytical examples were used for the purpose of engaging students in scientific argumentation (making claims based on evidence) and for the generation of analytical understandings (how to analytically interpret measurements of animal behavior). It was observed during the first half of the session when Adam, after showing the video of actual butterfly combat, shared the following slide with the class. This example stood out as producing the longest discussion in the lecture (13 minutes, Fig. 5):

Adam: First of all, I need to point out that these combats are not just these dainty sort of aerial dances that seem to us to be quite light and whimsical, that they are quite severe for the individuals that engage in them, as this picture will attest here, where *we see an older male with bits of its wings broken off* because just simply having engaged in a series of combats over the course of its life or the adult period so far, it has become damaged, *there generally is a cost* associated with engaging in these types of aggressive interactions...When we see the persistence of these males in the combats, there seem to be what are called age-related effects, *as they age their persistence in the combat increases*, meaning they don't give up as easily, as they get older and more damaged, *they seem to be becoming more and more persistent*.

To support the point that butterfly combats have a highly aggressive nature and come with a biological cost (severe injuries), Adam resorts to a realistic and richly detailed photograph depicting an individual butterfly whose wings were substantially damaged. Embedded into the graph itself, this photograph provides a *vivid example* (Brandon & Brandon, 2013) designed to strategically attract students' attention to the highly aggressive nature of butterfly combats—a generality clearly supported by the illustrative image. This is then followed by consideration of specific information (a quantitative data set) regarding butterfly age and persistence in combat—used as an empirical basis for articulation of the generality: "as they [butterflies] age, their persistence in the combat increases."

Analytical exemplification had the highest degree of dialogism with students making a total of nine interjections—considerably longer oral contributions:

Adam: Why would older males who happen to be more damaged be more persistent than the younger ones? Yes

Student 1: Perhaps this is one of the last chances for older butterflies to have offspring, *they need* to do it more than a younger butterfly would, *they still have* their whole life span to do that.

Adam: Ok, yes, let me just paraphrase, as *they get* older *they are* getting closer to the end of their life and may not have many more opportunities . . . their options are dwindling as *they get* towards that later stage, so *they have* more motivation or incentive.

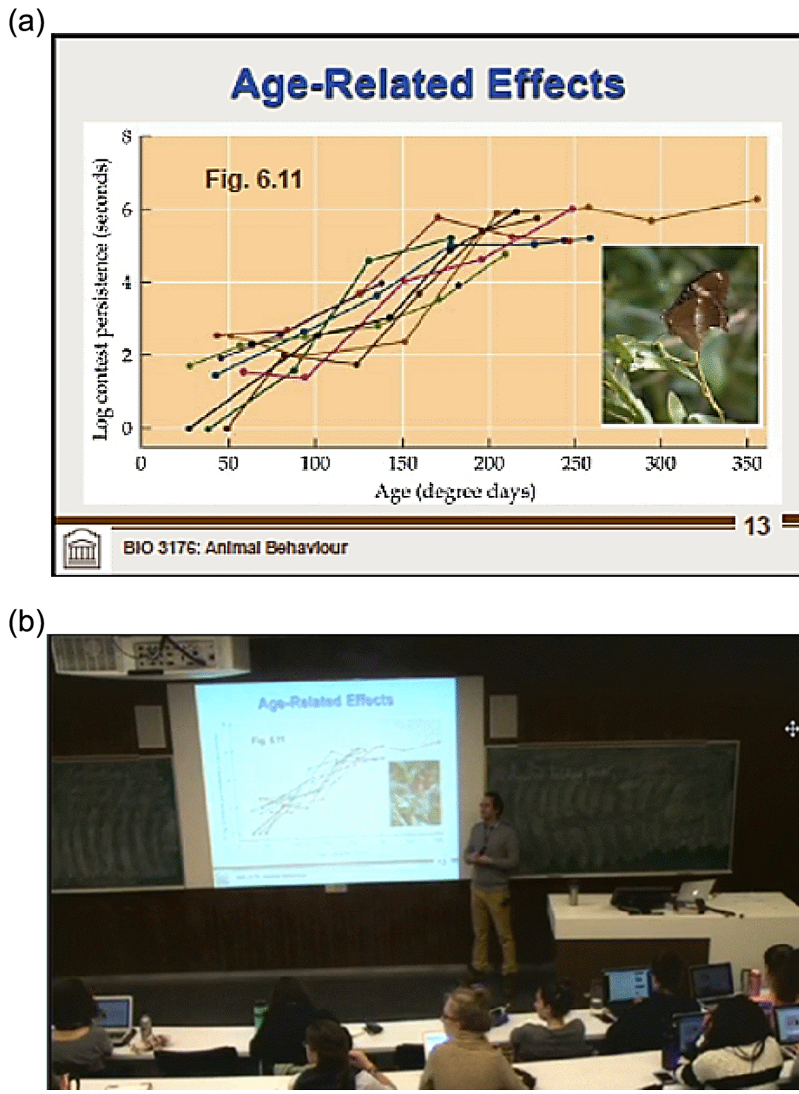


Figure 5. (**a**) Slide of analytical example of butterfly behavior and (**b**) instructor presenting course content related to the slide in class. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Student 2: With more experiences with combat maybe *they also learn* to some extent that by persisting and demonstrating a higher interest that *they can* out-compete *their* counterpart whereas *if you have* less experience in combat *you might* be more likely to more quickly spend higher energy cost.

Particularly evident in the above exchange is a shift in participants' pronominal choices from third to second person. Although male butterflies are initially reference as "they," there is uptake of Adam's anthropomorphized "you" in the second student oral contribution ("if you [butterfly] have less experience"). This suggests a shift in students' positionality from that of an observer to that of a male butterfly considering the biological costs and benefits associated engaging in combat at different ages (previously used by Adam during discussion of the wasp example). Participant exemplification served to socialize students into standard ways of making sense of animal behavior.

The practice of analytical exemplification was effective not only in encouraging students to express their thoughts scientifically but it provided Adam with a means to sustain discussions for extended periods of time. As the longest dialogic exchange in our dataset, the above discussion about age-related effects on butterfly territoriality lasted for approximately 7 minutes. Due to the long duration of this participant example and space limitations, we will skip several minutes ahead to the end of this analytical example:

Adam: We said what the benefits are, what are the costs associated with being a young butterfly that persists a certain amount of time versus being an older butterfly that persists a certain amount of time?

Student: When *you are* a younger butterfly *you have* more reproductive potential, like if *you get* damaged when *you are* really young *you have* less reproductive potential, so the cost would be much higher when *you are* younger.

Adam: So, when *you are* young *you have* presumably a great deal of potential in terms of having many more reproductive opportunities in the future, so the costs would be high of becoming damaged and perhaps of losing out on some of those future opportunities whereas if *you've* already lived for a certain while and presumably had a certain number of reproductive opportunities, then the costs of losing this time for *your last time* are much lower than *if you were* to lose this time for *your last* when *you are young* and presumably have so much potential. . .It's important to be able to put it back in the currency of the language that we use in this class through the studies of animal behavior, kind of presenting them as benefits versus costs and that the costs are much higher for a young individual who has great potential than for an older individual that is close to the end of their life anyway and then if this is the last one then *well, so be it because I had a good successful life up until now*. So*, they really have* much less to lose, these older individuals than the younger ones and that maybe partly why we see that those older individuals, despite the fact that *they are not* better, *they are* older, *they are* damaged, *they may be* weakened, *they may have* lesser fat reserves and the likes but, *gosh, darn it*, *they are* just going to give it *their all* because *what have I got to lose*? So putting it in terms of costs and benefits really helps to explain the economics of these decisions, why *you* would see in one case the types of behavior that *you* wouldn't expect in the other case because there is a shift in the trade-off between the costs and the benefits.

The discussion about the butterfly example ends with a high degree of dialogism. A noticeable feature in the above exchange is *heteroglossia* (Bakhtin, 1981) or plurality of voices. This is particularly evident in Adam's concluding utterance wherein he gives a sort of virtuoso heteroglossic performance by voicing the butterfly ("*what have I got to lose?*") while simultaneously commenting on its territorial behavior in the voice of a behavioral biologist ("they [butterflies] really have much less to lose") before transitioning back into the voice of a science instructor ("so putting it in terms of costs and benefits really helps to explain the economics of these decisions"). Furthermore, like much of the previous discussion about this analytical example, the above exchange is characterized by dialogic features such as interactivity (turn-taking), negotiation (uptake and elaboration of each other's ideas), social equality (interactional symmetry), spontaneity (emergent and unplanned topic development) and social closeness (informal and supportive relationships).

At an argumentative level, analytical exemplification is consistent with *inductive generalization* (Monahan, 2015), a type of reasoning wherein the arguer searches for a predictable pattern within a sample and then generalizes it to a larger population or class. This is precisely what Adam and the students accomplished in the above analytical example. Based on empirical measurement of contest persistence (how long an individual engages in a combat) within a sample of butterflies with varied ages, a general conclusion was drawn about the probable occurrence of similar age-related effects across the entire species, as well as in other animal groups. Lifespan-related measures of a few individuals' combative behavior served as evidential grounds for making the more general claim that older butterflies may generally be more persistent than younger butterflies.

Learning From Examples

Our data analysis revealed varied results on aspects of students' experiences learning with examples, including reading about examples, taking notes about examples, generalizing from examples, being engaged by examples and thinking through examples.

Reading About Examples. Many students reported not reading about the biological examples in advance due to factors such as limited study time and difficulty comprehending the complex and technical language of their textbook. Instead, students typically referred to the textbook in search of additional information about the examples discussed or additional examples subsequent to the whole-class discussion. As stated by the students:

> I do not read the textbook chapters before class.

> I do not normally read the textbook before class. I use the textbook to look into more information when studying the keywords.

> The lecture is the first encounter with the material, yet I still feel like I can extract the important concepts of the material from the lecture alone.

> I get a pretty good understanding just by going to class, I cannot rationalize having to read the textbook, I don't get any benefit from it.

For the above students, learning from examples did not involve prior reading of specialized science texts. Instead, these students' first encounter with biological examples generally occurred in the course of whole-class discussion. Furthermore, for students who subsequently read the textbooks, learning from examples typically included *transmissive reading experiences* (Sadoski & Paivio, 2007; Schraw & Burning, 1999)—silent engagement with expository texts focused on the identification and extraction of text-encoded meanings and passive reception of conceptual messages through decoding of a lexically dense type of writing.

Other students had different reading experiences while learning from examples. A few students reported reading about biological examples on their textbooks prior to their oral discussion. These students stated the following:

> Time permitting, I do try to read the textbook chapter before each class. I find that *reading beforehand helps lay the foundation for the class*, even though I may not fully understand or extract the general message from the reading at first.

> I honestly thought it [reading] was really useful because I had already seen all the info and once in class, like I was sitting there and I got the graphs right away and *I could really focus more* on like the concepts. . .*I didn't need to like focus as much* and make sure that I really understood in class as I know I already did.

The above students came to the classroom discussion with some familiarity with the biological examples discussed in class. This learning strategy provided them with benefits such as "focusing more on concepts" and "extracting the general message," which suggest that reading about biological examples can help prevent cognitive overload and promote student achievement of germane load particularly during classroom discussion of analytical examples (characterized by relatively high levels of complexity and informational input).

Taking Notes About Examples. Central to students' experiences learning from examples was the practice of taking notes, a task they accomplished either by handwriting on a printout of the instructor's slideshow or by typing on a computer laptop. Students commented on the importance of taking notes particularly during discussion of analytical examples. When asked about strategies they adopted to help them learn from examples, students replied:

> I briefly write what *the data shows*. . .I write a lot of notes to *describe the data* that is presented.

> I focus on taking notes on the *axis and trends in the graph* and why the experiment was done and what it proved.

> I would explain the *axis titles* and then *explain the data* presented. *Explain the trends seen on the graph*.

> *For graphs/experiments*: *Write down trends of study* as well as how they apply to the overall concepts.

> *Writing by hand* allows me to *add explanations of axes and figure* data right on the graphs themselves.

Particularly evident in the above student commentary is the strong association between analytical exemplification and note taking. As evident in the recurrent empirical references (*data*, *trends*, *graph*, *axis*), the above students expressed a shared concern for producing an informative written record of instances of analytical exemplification to which they could refer subsequent to classroom instruction. Parallel to their participation in whole-class discussion about analytical examples of animal behavior students sought to write down general descriptions and explanations for the empirical trends under deliberation. Adoption of strategic note-taking practice was particularly frequent among students who reported not reading the textbook in advance of classroom instruction. The focus on data-based analytical note taking by students may reflect a general lack of familiarity and/or confidence in their ability to draw meaning from graphically presented data from research results in science. This would therefore reinforce the pedagogical significance of the use of *analytical exemplification* for the development of these kinds of skills among the undergraduate students of science. It also underscores the importance of devoting more instructional time to analytical examples. Students who are less prepared for class are less likely to be able make sense of the concepts associated with analytical examples unless extra time is taken to work through or explain these examples.

Generalizing From Examples. While learning from examples, students also made a concerted effort to shift from the particular to the general. Typically this involved transcribing the contents of the on-going discussion, which contained a plethora of details, in more general terms without completely overlooking the specifics of discussed example. For many students, this proved to be a challenging task. As a student stated, "in class we get in a lot of detail about animals so it is difficult to express myself from a broader point of view." To overcome this learning difficulty, students sought to take notes strategically:

> When examples are being explained, I *generalize the concepts* without writing anything down about the example per se. . .I take down *limited notes about the example itself*.

> I try to write what is going on *without referring to the example itself*. For example, I use 'predator' and 'prey' instead of 'hawk' and 'nestling/egg'. . .I *avoid using specifics* such as species, location and environment. I *use general terms* to describe the concept or behavior, not the actual situation. . .I avoid as much as possible writing notes about the *examples in particular*.

> With each example we look at the *key terms* that are used to explain this behaviour and try to get as many *key terms* as possible to explain the behaviour and costs/benefits. . .I use the example to trigger *key words* in my head and go from there.

> Once all notes are written, I take the *lists of keywords* and go through them.

> Write down *the general message*/concepts that apply to the example, ex: write down specific cost/benefits as well as in general for the given behavior.

> I also try to *generalize the concepts* as much as I can while still trying to maintain the context of the example to show that the example is one specific situation and does not apply in all case.

As underlined above, the three main note-taking strategies deployed by the students were generalized reference, identification of key words and summarizing. While some students purposefully avoided making any written references to the specifics of each case (*species*, *location* and *environment*), others limited their writing to keywords, that is, conceptual terms that referred to general ideas or principles (e.g., territoriality and cost/benefit) and could be used to scientifically explain animal behavior across a variety of examples or cases. As a result, oral particulars were transcribed as written generalities.

Being Engaged by Examples. There was evidence in students' comments that the biological examples did indeed serve as a source of engagement as intended by the instructor. There was general consensus among students that the biological examples cited by Adam were overall engaging. As a student stated, "I think the examples are interesting, it [exemplification] helps me stay focused in the class, it keeps me in the lectures." Several students identified the examples involving territoriality with butterflies and "butterflies fighting" was a particularly engaging example. Nonetheless, students also cautioned about the importance of personal preference and presentation format when it comes to being engaged by examples. This was apparent in comments such as:

> It [engagement] can be kind of what interests anybody, it's going to be a very specific answer . . . it's kind of a personal preference, everyone likes different kinds of animals, different kinds of behaviors.

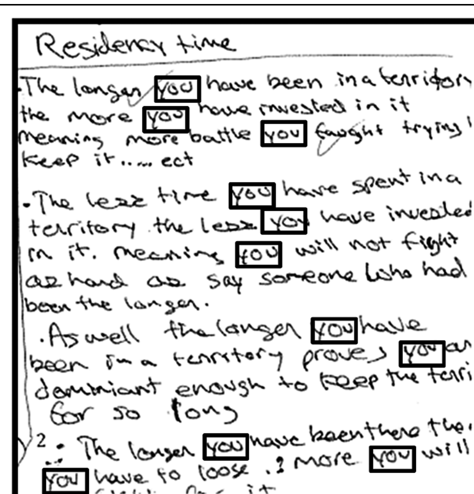
> [I find engaging] anything that is explained with an animation, whether it be from a video or physical demonstration. Visual aspects seem to work in my favor.

For these students, learning engagement originated not from inherently engaging examples such as instances of butterfly combat, but from diverse exemplification practice wherein instruction is centered on examples of a rich variety of biological topics that could appeal to a range of interests and strategic deployment of visual supports such as videos.

Thinking Through Examples. Students' comments also revealed that personification (imagining animals that animals possessed the human capacity of speech) served as a mental device for making sense of biological examples and producing scientific generalities. As a student wrote in her questionnaire, when engaged with an example of biological behavior, "I try to imagine myself as the animal in a way to better understand everything that goes on around him." For this and other students, Adam's practice of giving participant examples during whole-class discussion played an important role in helping them develop the ability to construct biological generalities from specific situations. Evidence of such can be found in Table 3 below which shows the striking linguistic similarities between a student's oral comments during the highly dialogic discussion of analytical examples of butterfly territoriality and subsequent student writing about this same behavior in a curricular artifact.

As can be seen above, there is a predominance of the generalized "you" in both the oral discussion and student written work. While discussing the effect of age on territorial behaviors, the student repeatedly adopts the perspective of butterflies with varied ages. The students' *you* does not refer to the Adam or a peer but to hypothetical and generalized butterfly at a particular stage of her lifecycle (a younger vs. an older organism). Likewise, when writing about territoriality, the same student adopts the perspective of a hypothetical and unspecified animal whose duration of ownership over a hypothetical territory is known (*you* = a general and unspecified animal). Rather than writing in the impersonal style typical of the specialized language of science (Lemke, 1990; Oliveira, 2011), the student produces a text with the same generalized second-person pronouns of the participant examples discussed in class (e.g., "the longer *you have been* in a territory" rather than "the longer a territory *has been occupied*").

Table 3
Student comments about territoriality

Oral comments	Written comments
Student: . . .if **you** [butterfly] have less experience in combat **you** might be more likely to more quickly spend higher energy cost Student: When **you** are a younger butterfly **you** have more reproductive potential, like if **you** get damaged when **you** are really young **you** have less reproductive potential, so the cost would be much higher when **you** are younger	 Residency time ·The longer you have been in a territory the more you have invested in it meaning more battle you fought trying to keep it.... ect ·The less time you have spent in a territory the less you have invested in it. meaning you will not fight as hard as say someone who had been there longer. ·As well the longer you have been in a territory proves you are dominant enough to keep the terri for so long 2· The longer you have been there the you have to loose . more you will

Discussion

We now consider the significance of our main findings.

Opening Dialog

As indicated above, different levels of dialogism were observed. Classroom discussion was characterized by higher degrees of dialogism when Adam gave the conceptual and analytical examples of animal territoriality. These types of exemplification were characterized by dialogic features, such as plurality of voices (i.e., heteroglossia), ventriloquism (speaking in the voice of anthropomorphized animals), interactivity (turn-taking), transactional exchanges (uptake and elaboration of each other's ideas), spontaneity (emergent and unplanned topic development), and social closeness (informal and supportive relationships). This stood in sharp contrast to the giving of a procedural example, which was characterized by monologism (i.e., transmissive instructor monologue for the most part devoid of student voice or active negotiation of meanings). While the small number of observed examples prevent us from drawing any definite conclusions, the occurrence of varied levels of dialogism across different types of exemplification suggests a potential causal relationship, a possibility deserving of further empirical examination by future research.

Two of Adam's examples (the conceptual and analytical ones) seemed to enable him to promote and foster an open classroom dialog. As highlighted in the previous literature, instigating classroom dialog with students requires making room for authentic and unscripted interaction (i.e., allowing students to autonomously engage in open discussion) as well as serious epistemological commitment to sustained construction of interpretation and active transformation of understanding (i.e., encouraging students to adopt a serious epistemic role as knowledge builders; Alexander, 2004; Nystrand, 1997). Likewise, the conceptual and analytical examples given by Adam served as a form of "epistemic invitation." These two forms of examples provided Adam with a compelling means to invite students to epistemically join a discussion open to collaborative exploration of ideas and perspectives. During discussion of these two examples, Adam's students shared a serious epistemic role as active co-constructors of knowledge and new insights, which they actively help generate through reciprocal transformation and mutual expansion of understandings. However, we again refrain from generalizing beyond the three examples examined given our limited evidential basis.

Taking the above finding as definite evidence that certain types of examples are inherently superior to others in fostering dialogism would be problematic and unwise given the complex and contextually emergent nature of language-mediated social interaction in science classrooms. There is increasing recognition among scholars that classroom language is a complex system that is both dynamic and nonlinear. As emphasized by Larsen-Freeman (1997), "language grows and organizes itself from the bottom up in an organic way, as do other complex nonlinear systems" (p.148). As such, exemplification is comprised of an aggregate of a multitude of interacting parts (imagery, speech, text, participant, setting, topic, etc.) and its associated degree of dialogism, contribute to the combined effect of an aggregate of contextual factors. So, rather than assuming a direct causality (univariate cause-effect link), it is more productive to conceive of the higher levels of dialogism during conceptual and analytical exemplification as a contextually dependent outcome inevitably characterized by a certain degree of indeterminacy, uncertainty and unpredictability. Similar levels of dialogism may be observed at different times and places depending upon dynamic interactions among various contextual factors such as initial conditions, feedback loops and adjustments within the discursive system. Put differently, using a particular type of example does not necessarily guarantee the emergence of dialogism during science instruction as this is in fact an emergent accomplishment contingent upon teacher implementation. Nonetheless, our findings indicate that, in the examined science classroom context, presentation of conceptual and analytical examples did seem to create initial conditions that were conducive to such an instructional outcome; a noteworthy finding in our view.

Experiencing Exemplification

Regarding students' learning experiences, our analysis revealed that the three example types given by the science instructor led to student engagement in varied types of argumentation: inductive reasoning by parallel cases, inductive reasoning by causation, inductive generalization and deductive reasoning. Additionally, student deployment of the indefinite *you* to articulate scientific generalities in writing indicated the possibility of emergent acquisition of the specialized language of behavioral biology. Nonetheless, because the indefinite *you* is commonly used in many forms of academic argumentation and explanation, it is not possible to accurately determine, based on the collected data, the extent to which use of this pronominal form by the students was the result of transfer of previous knowledge or skills being applied in this particular context (as opposed to acquisition through their exemplification experiences in this specific course).

The above findings highlight what participating students learned *through* the biological examples experienced in class. As deployed by Adam, exemplification served strictly as a means for teaching important generalities. However, there was little explicit discussion *about* exemplification itself. How to effectively select and present examples to an audience of biologists (i.e., accepted communicative practices in the field of behavioral biology) was never taken up as a topic of instruction or assessment. The findings of this study highlight an important shortcoming of using examples strictly as vehicle for arriving at scientific generalities. Such an instructional approach seems to provide limited opportunities for students to explicitly learn about scientific exemplification or develop exemplifying skills even though the practice of example-giving figures prominently in professional scientific communication such as published research articles (Hyland, 2007; Kanoksilapatham, 2005).

The main implication of the above findings is the importance of promoting student development of *exemplification literacy* (Zillman and Brosius, 2000), that is, the ability to critically assess the use of examples in scientific communication. Helping science learners and novices develop an informed awareness of exemplification itself is essential for the prevention of mis-exemplification (use of examples that are erroneous, untrue, distorted or biased) and for imbuing in students the capacity to recognize the potential for manipulation of exemplifying information through skills related to a critical analysis of information. Doing so will likely require systematic selection, planning, and delivery of examples by science instructors. As revealed by the reported findings, first and foremost careful consideration should be given to the specific nature of the content to be exemplified, that is, whether the science generalities being taught involve methodological understandings, derivation of concepts, or application of concepts. Such a consideration could serve as a basis for the instructor's assembly of a set procedural, analytical, or conceptual examples.

It might also be beneficial for science instructors to carefully contrast this set of examples prior to setting out to teach a particular generality. Several important factors should inform their selection process. As described above, it is important to consider whether the examples chosen present a diversity of views or positioning, such as allowing students to see biological scenarios from the animal versus the scientist's perspective. The former allows students to identify the ecological and evolutionary factors of relevance that may have impact upon the behavior in question, whereas the latter provides an opportunity to learn the scientific process from observation, through hypothesis and prediction testing, to the analysis and interpretation of research results. Attention also needs to be paid to the argumentative structure of examples (underlying rhetorical components such as data, claim, warrant, and qualifiers). Lastly, consideration needs to be given to the delivery style and its potential impact upon students' learning experiences. Some important questions in this regard include: What modalities are involved (text, imagery, videos)? Are there vivid images that can be used to strategically foster emotionality? Are there characters (e.g., animals) whose perspective can be voiced or dramatized? Which examples are more/less familiar to my students based on what the students may know based on their previous experiences and cultural backgrounds?

Once systematically selected, examples can be optimized to provide the students with as interesting and engaging a learning experience as possible. One one hand, instructors can appeal to their intellect in such ways as exploiting the "wow" factor inherent to studies of the natural sciences, in order to stimulate curiosity, and presenting seemingly paradoxical cases to improve their deductive and inductive sleuthing capabilities. On the other hand, instructors can appeal to their emotions and increase engagement in the course material. In order to resonate with this more intuitive side of students, instructors can strategically resort to "cool" examples, unusual ones, happy or sad examples, etc.

In addition to oral discourse, three mains facets stood out as central to how students experienced oral exemplification in the examined science lecture. These experiential dimensions were associated with the PowerPoint slideshow (how the instructor designed the slides used to present examples), textbook reading (whether or not students read about the examples under deliberation in advance), and note taking (how students approached the task of taking written notes about the examples being discussed). As described above, generally speaking, multi-modal exemplification (photographs and videos) fostered more engaging experiences while advance reading and reduced note-taking helped prevent cognitive overload among students. As a counterpoint to these aforementioned benefits of learning through exemplification, however, learning from examples was experienced by some students as a rhetorically and cognitively demanding activity that required adoption of coping strategies.

The above finding is consistent with previous research indicating that instructional activities involving multiple and often competing channels of communication (e.g., the combined use of talk and writing) can be challenging for students (e.g., Rounds, 1987). In traditional monologic lectures, students' difficulty stems from the need to listen while taking notes despite the fact that talk is faster than writing (complex input of information). From a communicative perspective, it can be posited that dialogic classroom discussions are even more complicated since students are also encouraged to speak in addition to listening and writing. However, students may not be able to simultaneously attend to all modes of communication (talking, listening, and writing) and as a result may take notes that are either incomplete or difficult to understand. Such a possibility highlights the importance of coping strategies such as those reported by our participants (structured and reduced note taking, focus on key words or ideas, etc.). Rather than simply assuming that science learners will naturally resort to coping strategies such as these, it may be more productive for science instructors to provide students with explicit discussion and guidance upfront on how to cope with the communicative demands of dialogic discussion of multi-modal science examples. Doing so will likely increase the chances that students may effectively learn from collective deliberation of science examples.

Conclusion

The present study contributes to the science education literature by highlighting the pedagogical value of exemplification as a potentially effective instructional tool. In much of the previous literature, giving examples is a practice mostly considered in terms of its evaluative value for the assessment of student learning. Asking science learners to provide an example is typically seen as an effective means to evaluate students' ability to apply a general rule, law, or principle. Example-based assessment items or prompts provide students with an opportunity to demonstrate having learned how to *apply* a previously taught concept or idea. This is particularly evident in science teaching methods books (e.g., Bybee et al., 2008; Chiappetta & Koballa, 2002) which commonly include provision of example at the Application level in Bloom's (1956) taxonomy. However, as the present study shows, exemplification extends beyond deductive application of generalized principles to particular situations as it can also be used for the purpose of inductively teaching science concepts to learners. The generative (inductive) use of exemplification in science can serve as powerful means to scaffold student conceptual learning. This is consistent with Watson and Mason's (2005) argument that "the teacher is in a position to construct tasks that challenge learners to explore and extend their example spaces [cognitive pool of familiar examples]" (p.70). The present study takes an initial step in helping teachers carry out such an instructional endeavor by identifying a set of exemplification strategies that can inform science teacher practice.

Nonetheless, it should be acknowledged that the present study is not without limitations. One important shortcoming was the scope of our analytical exploration, which, as indicated above, was limited to a single classroom event (a lecture on territoriality). Moreover, while the linguistic evidence available to us suggests that exemplification constituted a pedagogically rich and powerful vehicle for inductively engaging students in the examined lecture, additional research will be needed to determine the extent to which similar results can be found at different classroom contexts (topics, disciplines, grade levels, etc.). At a methodological level, our study is constrained by the limited scope of our datasets. While the data used for examination of instructor deployment of examples included only one class meeting, our data on students' learning experience was based on all thirteen course topics, over approximately 25 class sessions (our questionnaire and interviews did not focus specifically on the lecture on animal territoriality). As such, this study may lack the empirical basis for determining the extent to which students' self-reported experiences and discursive performance have been influenced by different uses of examples in other classes beyond the single lecture examined in this paper.

This study does, however, point to several potentially productive avenues for future research. For instance, one area that will need to be researched is unplanned or impromptu exemplification, wherein science instructors do not always take the time to plan their use of examples in advance based on a careful review of the curriculum. Consequently, analytical consideration remains to be given to pedagogical situations wherein the instructor needs to come up with an example in the moment, based on a formative assessment of the unfolding discussion. Attention also remains to be given to the teaching strategy of asking students to construct their own examples of scientific concepts. As emphasized by mathematics educators such as Watson and Mason (2005), pedagogical tasks involving example generation can provide learners with invaluable opportunities for transforming, re-organizing, extending and applying their conceptual knowledge.

In summation, conceiving of exemplification simply in terms of conceptual illustration does not do justice to this important and complex dimension of science instruction. Further consideration needs to be given to exemplification as a pedagogical tool that science instructors can strategically draw upon to develop students' example spaces as well as to promote important inductive skills, such as the ability to recognize similarities and differences across multiple instances, generalizing particular cases (i.e., rule formation) and appropriately qualifying generalizations. Such additional research, we believe, is likely provide science educators with much needed guidance on the types of examples available for teaching science and how particular types of examples can be effectively deployed to shape students' classroom experiences in ways that are more conducive to science learning.

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Appendix

Transcription Conventions

The following notation is adopted in all transcript excerpts included in the present manuscript:

<u>Underlining</u>	indicates key features of the provided excerpts.
?	indicates rising intonations
.	indicates falling intonations
[]	indicates observer comments
Italics	indicates shift in intonation

Student indicates a student's name has been removed for anonymity