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Memorable Exemplification in Undergraduate Biology: Instructor Strategies and Student Perceptions

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Abstract The present study examines the exemplification practices of a university biology instructor during a semester-long course. Attention is given specifically to how the instructor approaches *memorable exemplification*—classroom episodes identified by students as a source of memorable learning experiences. A mixed-method research approach is adopted wherein descriptive statistics is combined with qualitative multimodal analysis of video recordings and survey data. Our findings show that memorable experiencing of examples may depend on a multiplicity of factors, including whether students can relate to the example, how unique and extreme the example is, how much detail is provided, whether the example is enacted rather than told, and whether the example makes students feel sad, surprised, shocked, and/or amused. It is argued that, rather than simply assuming that all examples are equally effective, careful consideration needs be given to how exemplification can serve as an important source of memorable science learning experiences.

Keywords Science exemplification · Learning from examples · Undergraduate science · Episodic memory

The pedagogical and epistemological value of exemplification for science educators are yet to be fully elucidated. Rather than being problematized and theorized in more depth, science instructor use of examples has remained mostly unexamined and its effectiveness in shaping the students' learning experiences have been largely overlooked. Despite being a nearly ubiquitous aspect of science

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teaching and learning, surprisingly little consideration has been devoted to how experienced instructors deploy science examples in their teaching, the ways students respond to examples at various stages of learning, or to how novice and prospective teachers can effectively deploy examples. Exemplification has yet to be established as an area of research in the field of science education. This state of affairs is consistent with Lowrie and Ludermann's (2015) argument that, in scientific culture, the use of examples:

> Has often been demoted to mere didactic illustration of general concepts for those unable to understand them without assistance from concrete cases or instances… [as such] exemplification becomes a mere auxiliary to the business of knowledge, defined as the subsumption of particular events or appearances under general laws or rules (p. 4).

However, conceiving of exemplification as mere illustration overlooks the diverse and nuanced nature of exemplification as well as its potential as a pedagogical tool. Among other things, exemplification has been endorsed as a pedagogical practice that can foster social justice and equity—as a means to support the English learners' second language acquisition and enculturation (Dong 2013) and to accommodate students with special needs (Hall et al. 2012). Advocates argue, based mostly on theoretical grounds and personal experience, that carefully selected examples clearly linked to what learners already know can support student acquisition of abstract generalities (i.e., support inductive learning).

Exemplification is particularly important at the university level, where the traditional reading-style lecture remains the predominant method of teaching (Jones 2007; Sutherland and Badger 2004). In undergraduate lectures, students engage predominantly with impersonal written genres (e.g., traditional textbooks) that favor factual exposition and context-independent generalization (Maton 2013). The very high complexity of these impersonal science texts, combined with underdeveloped disciplinary literacy skills, too often reduces or precludes student acquisition of science concepts (Krajcik and Sutherland 2010; Norris and Phillips 2003). Furthermore, university science instructors frequently struggle with the problem of vigilance decrement (Young et al. 2011)—rapid decay in student concentration and attention in the course of a lecture. In an effort to determine the extent to which these challenging instructional problems can be countered through strategic example-giving, the present study examines the exemplification practices of a university biology instructor during a semester-long course. Attention is given specifically to how the instructor approaches *memorable exemplification*—classroom episodes identified by students as a source of memorable learning experiences.

Exemplification and Learning

In classroom discourse, exemplification is typically marked by the terms *for example*, *for instance*, *a case in point*, and *exempli gratia* (e.g.), all of which designate communicative situations wherein a concrete particularity is brought to bear as a way to illuminate an abstract generality. As Waldenfels (2015) writes, "the decisive point [about exemplification]… is that a gap opens up between the general and the particular that can only be crossed with a leap" (p. 39). The act of giving an example invariably entails selection of a single instance (the *exemplum*, *exempel*, or *beispiel*) that shares a number of features with other instances within a conceptual category (the exemplified). Because the chosen instantiation is singled out to represent a larger group or category, exemplification can be considered a process analogous to

extracting a sample from a larger pool of events or entities (Zillman 1999; Zillman and Brosius 2000). The presentation of an example brings to bear something concrete to clarify expression of a generality (concept or principle). As emphasized by Lipps (2015), "[because] an instance of something is given in order to show something 'through' it… the example always points to something beyond itself" (p. 21).

Evidence exists that exposure to exemplification can trigger a wide spectrum of emotional states ranging from mirth to surprise, sadness, and anger. As previously shown (Busselle and Shrum 2003; Gibson and Zillman 1994), the degree of emotionality felt by recipients can be manipulated (amplified or reduced) through strategic use of imagery with varied levels of realism, vividness, and distinctiveness. Biology teachers in particular have been shown to make strategic use of humorous examples for managing the students' emotions when teaching about controversial topics such as evolution (Goldston and Kyzer 2009; Oliveira et al. 2011). Serving as a source of enjoyment and satisfaction, these humorous examples encouraged students to experience positive emotionality (e.g., *fun*, *mirth*, *amusement*).

Exemplification has also been shown to have social and relational implications in classroom settings. This is particularly evident in studies that have examined the teachers' use of *participant examples*—oral descriptions of actual or hypothetical situations wherein the teacher presents herself and/or students as characters to illustrate topics under discussion (Oliveira et al. 2011). Because participant examples often exclude students and reinforce differences in social status, they can lead students to experience negative emotions (e.g., anger and sadness).

Evidence also exists that exemplification influences student cognition and learning. For instance, worked examples have been shown to have a positive effect on learning by reducing the cognitive load on the students' working memory (Spanjers et al. 2012; van Gog et al. 2010). Learning from worked examples prevents cognitive overload (excessively high mental load) and promotion of germane load (optimized working memory load) among novice learners engaged in cognitively complex tasks (problems). And, in our own previous work (Oliveira and Brown 2016), we have found that science instructors can use examples strategically to engage students in varied types of scientific argumentation and reasoning.

The previous literature provides compelling evidence that, depending on its communicative format and delivery, exemplification can influence students in diverse ways. In addition to supporting knowledge production and conceptual understanding, engagement with examples can help shape the learners' affective states and social relationships in science classrooms. This is particularly the case of *oral exemplification* (e.g., whole-class discussion of examples), which, if skillfully and thoughtfully facilitated, can serve as an effective springboard for guided meaning-making in the science classroom. In the present study, we empirically examine a university instructor' strategies in accomplishing this task, as well as his undergraduate students' perceptions of learning biology through exemplification. Our theoretical stance is described next.

Exemplification as Memorable Experience

In this study, we adopt an experiential perspective on exemplification. For us, giving and receiving examples constitute an important part of the students' learning experiences in science classrooms. The experience of being exposed to examples can be more or less memorable to students depending on a variety of factors such as frequency and recency of exposure; presence

of attention-drawing features such as emotion-evoking imagery, high levels of realism, and detail; and focus on unusual or extreme instances with a high degree of distinctiveness (Busselle and Shrum 2003; Zillman and Brosius 2000). Such exemplification experiences have been shown to be characterized by increased memorability (Zillman 1999) in the sense that they can be easily retrieved from memory subsequent to exposure. Memorable exemplification experiences are more readily accessible than others.

Informed by previous theoretical work on recall from the field of psychology, we make a distinction between semantic memory and episodic memory. Like Tulving (1972), we conceive of these as two distinct categories of long-term, declarative memory. *Semantic memory* refers to the students' general knowledge (e.g., facts, ideas, meaning and concepts)—factual information that is intentionally stored and can be consciously retrieved through recall. On the other hand, *episodic memory* is the students' memory of classroom experiences and specific events that occur during an undergraduate course, which can be explicitly stated and intentionally conjured through the process of recollection. This distinction is equivalent to that of knowing and remembering. Knowing is more factual (semantic) in nature, whereas remembering is an autobiographical feeling that is located in our collection of past personal experiences (episodic). Likewise, in the specific context of exemplification, students can be tested on their ability to recall factual information presented in the examples given to them or prompted to recollect their experiences being exposed to certain examples (see Fig. 1). Put differently, exemplification is characterized not only by semantic memorability but also episodic memorability. While the former has been the subject of a considerable amount of research, little analytical scrutiny has been devoted to the latter (i.e., the students' experiences as receivers of examples). The present study attends to this shortcoming by focusing explicitly on the episodic memorability of exemplification. Rather than dealing with student recall of the content of examples, our work focuses specifically on student recollection of their own exemplification experiences. As used in this paper, the term memorable exemplification refers to instructor-designed classroom experiences involving examples that students promptly recollect from their episodic memory.

As visually depicted in Fig. 1, we conceive of the students' experiences being exposed to examples as a cognitive process wherein episodic information is mentally encoded and stored

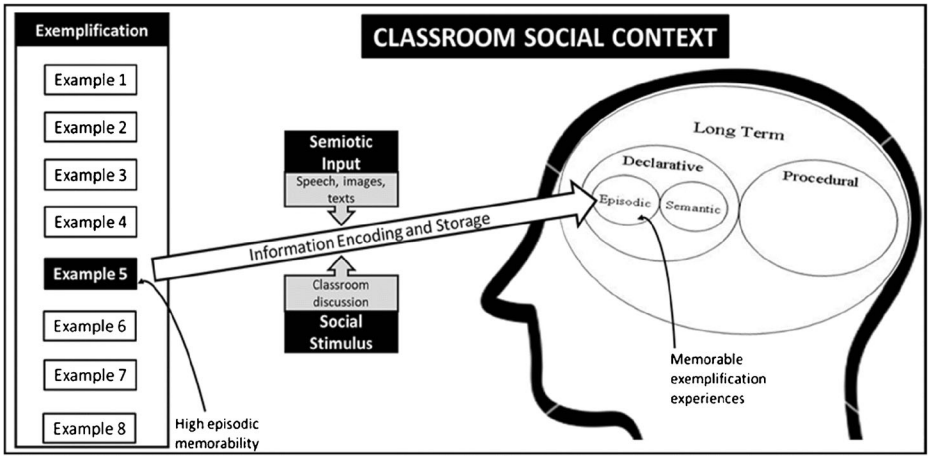


Fig. 1 Exemplification as memorable experience

in the students' long-term memory and can be later retrieved by means of prompted recollection. Furthermore, some exemplification experiences can be more memorable than others depending on the semiotic input and social stimuli at the time of encoding. If students are engaged and concentrating (paying attention) when given an example, encoding is effective and episodic information can be later retrieved from long-term memory with relative ease—the experience is perceived as memorable by students. On the other hand, if student attention is low, encoding is less effective, hence making it more difficult for students to recollect a particular exemplification episode (perceived as less memorable). In the present study, we set to identify possible links between episodes of exemplification that students recollect as memorable and the semiotic input and social stimuli strategically made available by an instructor when giving examples.

A premise central to our work is that examples given by a science instructor serve as a source of *episodic learning* (Nuxoll 2012). Used by psychologists with a phenomenological orientation to human memory, this term refers to an experiential, instance-based form of learning. From this perspective, classroom events are mentally stored by students as temporally indexed memories—when, where, and how something was learned. When an instructor gives a science example, students store retrievable information not only about the science concept itself but also about the episode of being given the example (the exemplification experience) from their point of view. Science learning is fundamentally a mental process wherein information is stored as a combination of episodic and semantic memories; memories of scientific information are mixed with memories of learning experiences had in the science classroom.

Methodology

The present study adopts a mixed-method research approach (Bogdan and Biklen 2003; Creswell 2007), relying mainly on descriptive data collected through open-ended research methods such as video recordings and surveys, which were systematically analyzed to build a naturalistic account (Lincoln and Guba 1985) of a biology instructor's exemplification practices and his students' perceptions with regard to memorability.

Participants

Participants in this study included a group of undergraduate students taking a third-year biology course on the topic of *Animal Behavior*. Enrollment consisted of a total of 78 students (58 females, 20 males) mostly in their early twenties. The majority was Anglo-Canadian with a minority of Franco-Ontarians. The course was taught by the second author (henceforth referred to as Author 2) who held a Ph.D. degree in biology and had approximately 13 years of teaching experience at the university level. Our selection of this particular classroom setting was motivated mainly by the exemplification-based instructional approach that was developed for the course. Selecting a research site where examples were used extensively served to ensure that data on our phenomenon of interest would indeed be available for collection and analysis.

Aimed at introducing students majoring in biology to the scientific study of animal behavior, this 13-week course focused primarily on the ecological and evolutionary causes and consequences of a variety of animal behaviors such as communication, altruism and sociality, territoriality, aggression, feeding habits, mating systems, and parental care. The course met twice a week for approximately 1.5 h per class. During these meetings, Author 2

typically used PowerPoint slideshows and video clips to engage students in the discussion of examples of animal behavior. Structured as *concept formation lessons* (Parker 1988, 2011), students engaged deeply with sets of related examples as they were guided by the instructor. Examples were used to support student inductive construction of generalities central to the field of behavioral biology.

The typical concept formation lesson was usually structured as follows. First, *introduction of the behavior* by watching a video of animals in the wild (e.g., the scientists' recorded field observations and clips from a documentary). This is followed by a whole-class discussion wherein students are encouraged to tentatively articulate a scientific interpretation of the observed behavior, posit predictions on the evolutionary causes, and are guided through a cost-benefit analysis. As part of this analysis, they generate a list of the costs and benefits associated with the behavior, as well as identify the contexts under which behaviors are adaptive or not. Second, *provision of experimental examples*—study(ies) designed to test the optimality of the behavior as a function of the costs and benefits—followed by a joint analysis of the data from graphical results provided. Third, *provision of comparative examples* showing varied animal groups under similar selective pressures and illustrating how similar behaviors evolve under similar ecological and evolutionary contexts. Fourth, *presentation of additional examples* of increasing complexity such as cases involving animal traits with opposing adaptive values, experimental studies designed to separate multiple factors, and examples that illustrate theories related to the behavior (e.g., optimality theory, game theory). Lastly, *articulation of scientific generalities* (concepts and principles) and discussion of larger implications to survival and strategies in animal behaviors that allow them to balance risks associated with ecological challenges and threats.

Data Collection

To characterize the instructor's exemplification practices, all course meetings throughout the semester were video recorded using the Echo360 Active Learning Platform (Echo360 2015), a computer system of lecture capture that can be used to digitally record audio and video of an instructor on a podium, as well as materials displayed through the projector (e.g., PowerPoint slides). Through the use a wide-angle ceiling camera located in the back of the room and a high-sensitivity lapel microphone worn by the instructor, this minimally intrusive system enabled capture of the instructor's actions as well as student comments, thus being particularly well suited for the naturalistic study of social conduct without any form of researcher bias or interference.

To examine the students' perceptions of prevalent exemplification experiences, we collected survey data at the end of the course. In this survey, students were asked to identify exemplification episodes they found to be particularly memorable. More specifically, students were provided with a written prompt that asked them to identify an example they encountered at any point of the course that they remembered particularly well and to explain what had made the chosen example memorable to them. Our methodological approach was consistent with the survey tradition of questionnaire self-completion where information is collected in writing from individual respondents (Robson 2002). The survey was completed by 74 students; four were not present the day the survey was administered.

Our survey prompt was designed specifically to target the students' episodic memory (as opposed to their semantic memory). This was motivated mainly by our analytical goal of better understanding how science instructors can strategically design exemplification experiences

that are more memorable to students (rather than simply increasing their recall of factual information). Using data collection techniques such as free recall, cued recall, and serial recall (Bernard 2002) to simply measure student retention of scientific facts would have been inconsistent with our experiential focus on improving the students' exposure to examples. Data on student factual recall would have been of limited value as a source of new insights into how to improve the undergraduate students' science learning experience science instruction. Moreover, it would also have been inconsistent with our belief that science exemplification should be aimed at higher-order cognitive outcomes such as comprehension and understanding.

Data Analysis

Our analysis of memorable exemplification was accomplished through the iterative and combined use of interpretative and flexible methods of analysis such as close reading, open coding, and memo-taking (Bernard 2002; Emerson et al. 1995). First, we sought to characterize the instructor's exemplification practices. To this end, we compiled a comprehensive and chronological list of all 172 examples given throughout the course based on a systematic review of our transcribed videos (available as supplementary material).

In our second analytical step, we turned to the students' survey responses. More specifically, we sought to identify those examples that were memorable to students (recurrently identified by our participants as such). Although most respondents identified a single memorable example as prompted, others did not. Four students refrained from identifying any examples as memorable (did not respond to the survey prompt). In contrast, a couple of other students mentioned more than one example in their responses. For instance, the following student identified three different examples as memorable rather than one:

> I remember well the example where the *female [mantis] would eat a male after copulation* in order to have an "easy," close, accessible food supply for its offspring. It stuck with me because of the fascination to why this would occur. Also, the praying mantis video was pretty cool. So mainly the *infanticide*, *siblicide* and *the case mentioned above* arouse my attention and wonder of animal behaviors and reason for it.

Investigating the participants' own judgments helped improve the credibility of this study by ensuring that our analysis constituted an accurate representation of their learning experiences (Clandinin and 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 and survey data, we sought to create analytical consistency and provide a trustworthy account of the phenomenon at hand.

We then conducted a qualitative multimodal discourse analysis (Kress et al. 2001)—a systematic examination of the multiple semiotic resources deployed by the instructor during classroom delivery of the small set of biological examples most frequently identified as memorable by the students. With a micro-genetic focus on unfolding short-term processes in face-to-face communication (Wertsch and Hickman 1987), this discourse analysis attended to minute contextual details of memorable exemplification along multiple modes of communication, including visual representation (imagery such as photographs, diagrams, and videos), spoken language (commentary, word choices, discursive moves, etc.), and non-verbal moves (hand gesticulation, body movement, etc.). Based on this analysis, we identified the main types

of semiotic input and social stimulus made available by the instructor during classroom delivery of memorable example to students.

Aligned with the research tradition of discourse analysis, we examined interactive semiosis (collaborative meaning-making related to a science phenomenon or concept) in naturally occurring speech. More specifically, we sought to identify the types of signifying acts that may render some examples more meaningful/memorable than others by closely scrutinizing the participants' co-deployment and integration of multiple semiotic modalities or sign systems (spoken words, gestures, and pictorial representations). Our analytical focus on how memorable exemplification is discursively accomplished is typical of discourse-centered research which, as Farnell and Graham (1998) point out, "involves making an inventory of distinct forms, both marked (not typical) and unmarked (typical), and the contexts in which they occur" as well as careful consideration of communicative functionality (p. 421).

Findings

Instructor Strategies

A total of 172 distinct examples of animal behavior given throughout the duration of the course, with an average of approximately 13 examples per week. Exemplification was invariably centered on the public display of carefully designed multimodal pedagogical artifacts (slides), often combined with anthropomorphized dialogue. The instructor's exemplification practices invariably involved PowerPoint projection of still images (photographs and diagrams) as well as moving images (short video clips) that visually depicted particular instances or manifestations of animal behavior. Usually with very little text, the slides for each example varied in their visual and verbal content. Three examples (Seychelles warbler, praying mantis, and honey bee) had multiple slides.

Student Perceptions

Fifty-three of the 172 examples were brought up in the 74 student responses. While the majority of these examples were mentioned only once by a single student, a few stood out as being recurrently mentioned by many different students. The examples most commonly mentioned were the spotted hyena pseudo-penis (nine students), the honey bee's waggle dance (five students), the red-headed coots' rejection of progeny (four students), and the ground squirrels' alarm calling (three students). For sample student comments on memorable examples, see Table 1.

Particularly evident in the previous commentary (Table 1) is the wide spectrum of emotionality experienced by students during memorable exemplification. Mental encoding of memorable examples was colored by positive as well negative emotions. For instance, students reported their experiencing of positive emotions *love*, *fun*, *interest*, *amusement*, and *fascination* when given the honey bee's waggle dance and spotted hyena pseudo-penis examples. While some expressed surprise and fascination due to perceived inconsistencies between biological form and function (*I can't get over the fact they* [female hyenas] *give birth out of them* [appendages]) and perceived similarities to human beings (*in a way that seems almost human*), others derived enjoyment from the instructor's theatrical rendition of the honey bee's waggle

Table 1 Sample student comments on memorable examples

Example	Week of class	Student comments
Spotted hyena pseudo-penis	8	The example has to be the pseudo-penis of the female spotted hyenas. It was amazing to see such a drastic form of physical male mimicry occur despite the seemingly costly aspects of birthing through the appendage.
		The example that comes to mind right away is the one of the hyenas and the pseudo-penis used to explain how hormones as well as social relations can play a role in evolution of physiology. I found this super interesting because something you would assume is completely unrelated can become a major part of a behavior developing. The result of testosterone being the formation of the pseudo-penis and how it was selected for as being a desirable trait simply because it meant the female was more aggressive was super cool.
Honey bee's waggle dance	6	I remember the waggle dance as I work with bees in the summer and I learned a lot more about it than I previously knew before taking the class. It's also a very fascinating behavior with still lots to learn and discuss. It stuck with me because of how interesting and amazing it is, how bees using the sun and gravity to improve their foraging efficiency.
		I loved learning about the waggle dance in bees! I found it to be an amazing adaptation to eusociality and resource gathering/sharing. Bees are incredible animals and the waggle dance has encouraged me to consider studying bees in my graduate studies.
Coots' rejection of progeny	6	The example of parental care with the coot chicks. I think it stuck with me the most because it seems like such a cruel way for a parent to treat its offspring. It was such an unexpected behavior but makes sense when looking on it from a fitness standpoint. I think it will stick with me after this course because it shocked me and it was so sad to watch.
		The red-headed chick example was really sad but it was also interesting to see why the animal does it.
Ground squirrels' alarm calling	12	My favorite example is the Belding's ground squirrel warning tactic in which one may sacrifice itself for the group. It was interesting to see how an animal would sacrifice itself for another's survival in a way that seems almost human by heroically and selflessly giving its life for another's.

dance example. In sharp contrast, students who recollected the coots' rejection of progeny example reported experiencing negative feelings such as sadness and shock.

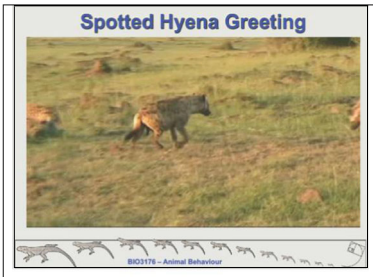
Another noticeable finding was that memorable exemplification spanned the entire second half of the course (weeks 6–12). Rather than being limited to more recent examples given during the final weeks of the course, student recollection of memorable episodes reached back to the mid part of the course as evident by the fact that two of the memorable examples were given during week 6.

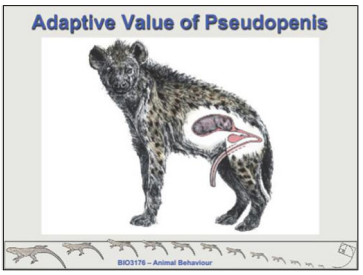
Semiotic Input and Social Stimulus

We now describe the socio-semiotic stimuli present in the classroom during encoding of each of the four memorable examples identified by the students.

Spotted Hyena Pseudo-Penis This memorable example was given during a lecture on the evolutionary development of communicative behaviors across various species of animals. Classroom delivery of this example entailed watching a short video clip of two female hyenas' "greeting" (produced in a documentary style by biologists in the

field) and whole-class discussion of various pictorial representations of the female hyenas' anatomy (week 8):





Instructor: Ok, we have Spotted hyenas… so we see normal behavior for cats and dogs, basic anal and genital sniffing, it gives lots of information about hormonal status, and is important for determining social ranks and so on. However, please note that there is a **big, looong, dangling appendage** hanging down here (pointing) that's particularly of interest to the hyena that's sniffing… at face value, nothing seems to be **strange** here, if any of us have ever met a dog for the first time, you'd recognize the behavior, that's what they do, it's part of the social dynamic of many animals to go around sort of sniffing one's anal or genital regions… and I wanted to point out that one of the individuals whose genital region was being sniffed quite energetically or enthusiastically has this **dangly appendage** here, and I'm saying it that way not to be funny, I am not calling it a penis because that's a female… so we have a **unique particularity** about the Spotted hyenas wherein the females have a fake penis known as a pseudopenis… what seems to be **unusual** here is that the individuals being sniffed at in this example are female, and what's being sniffed at more specifically is this big fake penis that a female Spotted hyena has, so that should be kind of **weird**, it should be **unusual** enough that we ask ourselves *what is going on here*?

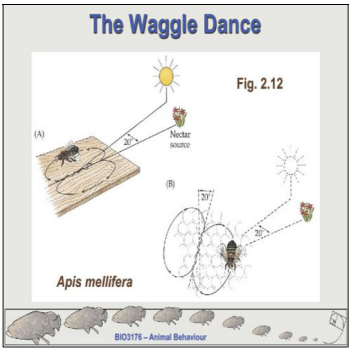
The semiotic input and social stimulus made available by the instructor when giving the above example were characterized by a high degree of distinctiveness. Rather than presenting a stereotypical instance commonly observed across various species of animals, Author 2 resorted to an extreme example—a highly unusual illustration.

Without initially revealing that the hyenas being observed were actually females, the instructor repeatedly used the term "dangly appendage." His reference comes across as humorously imprecise as it appears to violate of the stylistic norms of science talk (Lemke 1990) that usually govern science classroom discourse. Only later, does he explain the reason for his word choice (*I'm saying it that way not to be funny, I am not calling it a penis because that's a female*). This delayed and unexpected identification of hyenas with penis-like appendages as females stood out on cognitive grounds. Such an atypical categorization gave rise to cognitively marked conceptual operations that helped students easily remember this example. As emphasized by scholars of cognitive linguistics (Evans and Green 2006), basic-level human categorization is based on perceptual stimuli such as shape (a cognitively economic way of assessing group membership) and the perceived correlational structure of the world around us. Regarding the latter, Rosch (1978) writes "wings correlate with feathers more than fur" (p. 31). Likewise, the presence of appendages in the genital region typically correlates with the male category rather than female. As such, this example defies basic-level gender categorization based on perceptual verification of body shape. Rather than reinforcing the students' expectation that non-human gender is a category with clear boundaries, it introduces conceptual fuzziness (male/female as a problematic distinction). More specifically, it challenges the intuitive notion that having an appendage in the genital area is a necessary and sufficient

condition for membership of the male category. The salient dissimilarity to more traditional female body prototypes (idealized reference points) is what makes this an extreme example.

Overall, a total of four extreme examples were present in the student's list of 53 memorable examples. These included the spotted hyenas' pseudo-penis as well as the egrets' siblicide (identified by a student as "extremely sad & off putting"), the brown-headed cowbird's mafia behavior ("brood parasitism can be extreme"), and the Coots' rejection of progeny ("it seems like such an extreme and cruel way for a parent to treat its offspring"). All of these examples dealt with highly unusual cases unlike most others in the animal kingdom, being identified by the students themselves as extreme cases.

Honey Bee's Waggle Dance This memorable example was given during a discussion on the evolutionary development of altruism and sociality in animals (week 6):



Instructor: This dance is known as the waggle dance because it emphasizes the movement of the abdomen in a waggling fashion… the waggle dance will be done on a surface, and if that surface is vertical the angle of direction when **you** leave the hive will be the angle between gravity and the orientation of the dance. If that dance is done on a horizontal surface, it's the angle between the sun and the source that will be the direction that **you** need to take once **you** take off and leave to get it… basically, there is directionality to the dance, and the directionality involves waggling down the little dance piste and circling back to the beginning, doing this figure eight, and doing this enough times until the right number of helpers have been recruited… and the more food that is available, the more intense that waggling will be, and the longer the dance floor, in order to say *there is a lot of food*… so, they waggle, waggle, waggle (1-3), loop back to the beginning (4), waggle, waggle, waggle, move down to the back (5)… the angle between myself and say the sun, which is over there (6), this is the angle that **you** need to take (7) when **you** leave the hive to go and get the food (8)… so they are able to transmit information about there being food, how much food, what distance, what direction, and how many individuals we need to help us go out there and collect it all.

The semiotic input and social stimulus made available by the instructor when giving the above example was characterized by a high degree of theatricality. After quickly explaining the biological context of the scene (a bee communicating to others that a food source was found) and explaining its biological context, the instructor strategically resorts to theatricality (Fig. 2). The instructor physically re-enacts the bee's behavior, resorting to an anthropomorphized dialogue (*there is a lot of food… this is the angle that **you** need to take when **you** leave the hive to go and get the food*).

Author 2 selects a scientific image wherein a single bee (the main character) is portrayed performing the waggle dance against a white and neutral background mostly devoid of contextual details such as the hive's walls and the other bees in the audience (i.e., performance takes place on highly a generic and unspecified "stage"). Further, following mathematical conventions, imaginary dotted lines are used to identify relative position, path, and directionality implicit in the bee's physical movement (the choreography) in metaphoric space. This pictorial representation has a narrative visual structure (Kress and van Leeuwen 2006) in the sense that it visually narrates the unfolding actions of a character (the bee). Like a narrative text, the diagram depicts characters doing something to or for each other (i.e., provides a

dramatization of a particular event). The action being visually narrated has an internal spatiotemporal orientation or directionality that is graphically captured through the drawing of imaginary lines or vectors. Put differently, its visual message is spatiotemporally structured and directional.

Overall, a total of six theatrical examples were present in the student's list of 53 memorable examples. These included (1) speaking to students in Glaswegian Scottish (brogue) while enacting birds singing in different regional dialects; (2) acting like a Praying mantis with its head cut off, as if moving spasmodically as all nerve ganglia fire uncoordinatedly; (3) doing a Mick Jaggeresque strut to re-enact the mating dance of birds that are seen as super sexy; (4) physically demonstrating the push-up behavior of lizards; and (5) mimicking the stotting of the gazelle. Like the honey bee's waggle dance, these theatrical examples involved re-enactment (miming, mimicking, etc.) in which the instructor took on the role of the animal whose behavior was under deliberation.

Coots' Rejection of Progeny This memorable example was given during a discussion of parental care behaviors (week 12):

Instructor: What we see here is a little coot bird, and this little bird, as cute and fuzzy as it is, will either get loving care or will be forcefully rejected by their parent, dependent on qualities that we can see right now about the redness and the orangeness around their heads like this (pointing)… And here what we have is an **unfortunate situation** [showing video] where an individual in the brood is being chosen to be not only disinvested in, but is actively being shunned away from the rest of the family. And, I know this is a really **terrible thing**. You know, as a parent myself this really tears me up to see this and I can't imagine what it's like for an offspring who is so dependent on its parent to be shunned in such a way… and it really is **heartbreaking**. But then, we have to kind of get over those emotions if we're going to be studying animal behavior and say: *well, why does this happen?* Because it doesn't just happen in a weird context where one parent is abusive compared to the population, this is the way it happens in this species and it happens this way in many other species as well. And so, the question would be: *why?* Why then is there a single individual that is chosen to be outcast from the rest of the family and in such a **sad situation** neglected so vigorously, even violently such as in the way that we just saw.

The semiotic input and social stimulus made available by the instructor while giving the previous example were characterized by a high degree of vividness (detailed and realistic of animal suffering). Rather than presenting the coots' behavior in a more detached manner as an instance of non-human parental care to be objectively examined, the instructor explicitly discloses his felt emotions as a human parent who is touched by the biological situation under consideration (*as a parent myself this really tears me up*) and utilizes emotional labels such as *unfortunate situation*, *sad situation*, *terrible thing*, and *heart-breaking*. He positions himself as an emotional parent trying to biologically understand non-human parental care rather than a

biologist who remains unmoved by what, from a human perspective, can be considered a tragic case of offspring abandonment. The instructor resorts to a highly realistic photograph of a baby coot rejected by its parents. The picture is framed as a very close shot that captures the baby bird's facial expression in detail and depicts it looking directly at the audience (as if making eye contact with viewers). Such a photographic framing has been shown to be used strategically by photographers to trigger emotional responses in viewers, such as sympathy and compassion (Kress and van Leeuwen 2006; Retzinger 2013). Likewise, a public display of the previous picture served to encourage students to look upon the baby coot's "eyes of suffering" and gave its tragic abandonment a face.

Overall, a total of four vivid examples were present in the student's list of 53 memorable examples, namely (1) the coots' rejection of progeny, (2) the female giant water bugs' infanticide, (3) the great egrets' parental tolerance of siblicide, and (4) the red-headed beetles' coercive sex. Focused on detailed and highly realistic images of animal suffering and pain such as photographs of physically harmed bodies and video footage of social ostracism, these examples invariably dealt with contentious and sensitive behaviors that are often stigmatized in modern society.

Ground Squirrels' Alarm Calling Classroom delivery of this example occurred during a lecture on the evolution of altruism and sociality in non-human animals (week 6):

Instructor: This animal is exhibiting a behavior whose role **we** would probably assess as helping others. But **let's** now focus on the cost/benefit aspects to undertaking a behavior that can be seen as being helpful for sure, but also not without its own inherent costs… so, **we**'ve got these Ground Squirrels that are clearly making an alarm call at the presence of a predator… these Ground squirrels' societies are highly colonial, **they** live in a big colony in these subterranean burrows… so, **we** are talking about colonial nesting animals and one benefit is warning others of the danger… a cost is that it draws attention to **yourself** in the process, if **you**'re going to be warning others, **you** are increasing **your** own conspicuousness, which can be seen as a real danger… that can lead to serious challenges including losing **your** own life.

The semiotic input and social stimulus made available by the instructor while giving the previous example was characterized by a high degree of relatability. Focused on animal behavior commonly perceived as being associated exclusively with humans, students could relate these examples to their own previous personal experiences or to observed human behavior more generally. As can be seen previously, although a more removed and detached perspective of an external observer is initially taken (e.g., *this animal*), the instructor pronominal chooses to shift from third to second person (*if you're gonna be warning others, you are increasing your own conspicuousness*), hence encouraging students to see themselves as the squirrel. By promoting student adoption of a more involved internal perspective, the instructor increased the chances that these examples would indeed resonate with students on a more personal level. Because the biological situations being exemplified shared a high degree of similarity with familiar human situations, students could relate to the animals whose behavior was under consideration. This is consistent with Shepard's (1996) argument that "the meaning of animals is implicit in what they do: eat, run, leap, crawl, display, call, fly, mate, fight, sing, swim, hide, slither, climb and die… animals are concrete; their system is a categorical grid on which human roles can be fitted with name and ensign" (pp. 10/102). As such, animal behavior

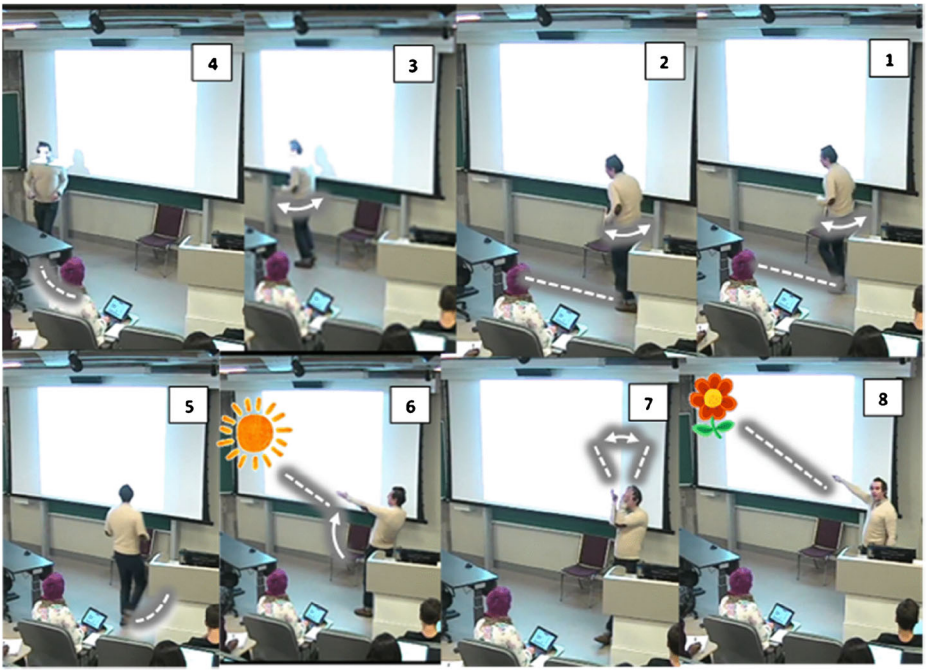


Fig. 2 Theatrical performance of the bee's waggle dance

can serve as a means for metaphorically understanding and objectifying social abstractions such as family heroism.

Overall, a total of 20 relatable examples were present in the student's list of 53 memorable examples, including the female burying beetle's forced monogamy on males, ring-billed gull and the emperor penguin's adoption of offspring, the long-tailed manakin's "wing man" dancing behavior, male hamster helping the female give birth, the crows' "generous" calling to others to alert them of a potential feeding, the zebra finches' preference of novelty, and the male iguana's premature ejaculation. As the most oft-cited category in the students' comments, relatable examples focused on animal behaviors that students perceived as being associated exclusively with humans and that students could somehow relate to their previous personal experiences.

Discussion

In the examined biology course, memorable exemplification was associated with four main socio-semiotic features, namely distinctiveness, theatricality, vividness, and relatability. The undergraduate students' increased episodic memorability was linked to the availability of semiotic input and social stimulus with such discursive attributes during encoding of exemplifying information, being mediated by their experiencing of emotionality and involvement. The significance of this finding is now discussed in light of previous empirical and theoretical work.

Recency of Exemplification

As reported previously, memorable exemplification spanned the entire second half of the course, with two of the examples that stood out in the students' episodic memory being given midway into the semester. This finding is in contrast to previous psychological studies that have identified a *recency effect*—a tendency among people to recall the last items in series best (Coleman 2006). Because latter items in a sequence are still present in the working memory when recall is solicited, they can be retrieved more easily. Based on this research, we expected examples given during the end of the course (week 13) to be more memorable to students. However, this was not the case. While one memorable example was given fairly close to the end of the course, others had been given several weeks before during weeks 6 and 8. This suggests that serial position (the position of an example within a sequence) may not constitute a strong determinant of student memorability when dealing with semester-long exemplification lists. In such a long time span, discursive emotionality seems to a certain extent offset recency effects, making exemplification stand out in the students' episodic memory weeks after being experienced.

Distinctiveness and Vividness

Another finding was that episodic memorability in students was linked to the availability of semiotic input and social stimulus with high degrees of distinctiveness (focus on extreme situations highly distinct from the usual) and vividness (highly realistic and detailed presentation of situations involving animal suffering). The presence of such features during instructor delivery of examples triggered a ranging of positive and negative emotions (amusement, unexpectancy, sadness, shock) that rendered the students' exemplification experiences highly memorable. This is not a novel finding, as both features have been previous linked to memorable exemplification. As indicated previously, evidence already exists that using emotion-evoking images with high levels of vividness and focusing on extreme instances tend to make examples more memorable to receivers (Busselle and Shrum 2003; Zillman and Brosius 2000). Such memorability stems from the humans' tendency to attend to and mentally record exceptional amounts of detail during emotional situations, often in the form "flashbulb memories" (Tulving and Craik 2000). This is further corroborated by our results.

The previous finding is consistent with previous research on emotionality in science education. A number of studies have recently examined the emotional dimension of the students' science learning experiences in high school settings (Ritchie et al. 2013), middle school settings (Tobin et al. 2013), and university settings (Hong and Greene 2011). These studies have consistently shown that the quality of the students' science learning experiences is closely linked to their classroom's emotional climate (Bellochi et al. 2014), being generally more positive and of higher quality during participation in multimodal activities such as interactive science demonstrations, discrepant events, and role-playing. This is precisely what our results show.

Relatability

Another important finding was a seemingly strong link between memorability and relatability of examples of animal behavior. As described previously, examples of animal behavior commonly perceived as being excusive to humans (e.g., the altruistic squirrel who "heroically"

draws the attention of an approaching predator) figured prominently in the students' episodic memory. Ability to relate these examples to their own previous personal experiences or to human behavior more generally enhanced the students' recollection of these exemplification experiences. This novel and noticeable link is deserving of further consideration.

An important discursive feature of relatable examples was that they typically involved topics such as family (the red-head coots' rejection of progeny), body shape and gender (the female spotted hyenas' pseudo-penis), perceived human-like conduct (the ground squirrels' alarm calling), and peer communication or interaction (the bee's waggle dance). These highly memorable examples can be grouped into three general categories of animal behavior (parental care, communication, and sociality/altruism). These examples tended to resonate with students on a very personal level by triggering mental connections to their personal lives (family experiences, people encountered outside the science classroom, and familiar social situations). On the other hand, several other categories of animal behavior did not figure prominently in the students' memories, including survival and feeding behaviors, choosing where to live, reproductive behaviors, and mating systems. In this course, the students' learning experiences with the latter categories of behavior were not as memorable. Put differently, some of what behavioral biologists consider to be *essential phenomena of animal behavior* (Bednekoff 2005) can be more relatable to students than others.

Another salient discursive feature of relatable exemplification was reference to mammals and birds. Participants in the present study showed a propensity to relate to mammals and birds as evident by their emotional responses to mammalian and avian illustrations. The students' emotional reactions seemed rooted in their humanistic values (emotional bonding) as well as their aesthetic values (physical appeal and personal fascination) toward these particular classes of animals (Kellert 2002). This is consistent with research showing that humans usally have stronger affinity toward mammals and birds than other taxonomic groups (Blouin 2012, 2013; Melson 2001). Therefore, it can be argued that their biological similarity to humans fostered increased propensity to *social relatedness* (Myers and Saunders 2002), that is, students more easily accepted mammals and birds in memorable examples as social others with whom they could relate emotionally, morally, and empathetically. When it comes to ensuring the relatability of examples, our findings suggest that careful consideration needs to be given the type of the animal (the agent is a member of a charismatic species or class) as well as what the animal is doing (whether the action is human-like or not).

Theatricality

Lastly, it is noteworthy that memorable exemplification was characterized by a high degree of theatricality. As reported previously, classroom delivery of the bee's waggle dance example involved theatrical performance, that is, physical re-enactment of the illustrated animal behavior. Unlike other examples whose delivery involved mainly pictorial-verbal reconstruction of animal conduct, the semiotic input and social stimulus made available during delivery of this example was characterized by a performance-oriented style centered on the imitative, dramatic representation of animal action and/or vocalizations. Rather than being simply stated and photographically depicted, the animal behavior was also physically dramatized with a high degree of animation and expression (movement, hand gestures, facial expression, body language, varied voice tone and pitch). In other words, theatrical exemplification had an additional performative dimension that served as a source of extra sensorial input and increased engagement, hence rendering it more memorable and mentally accessible to students.

The pedagogical value of drama activities in science has been previously highlighted in studies showing that complex and abstract science concepts as varied as chemical formulas (Aubusson and Fogwill 2006), ecosystems (Bailey and Watson 1998), states of matter (Varelas et al. 2010), and wavelengths (Dorion 2009) can be theatrically enacted and as a result afford students deeper scientific understandings. Conducted in K-12 settings, this literature provides evidence that richer meaning-making and deeper scientific knowledge co-construction can be promoted by theatrical means such as role-playing. Our findings underscore the possibility of theatrical rendition of examples also being beneficial at the undergraduate level. Enacting rather than "telling" a science example can make it memorable to students.

Limitations

The present study highlights the importance of further empirical examination of the practice of science exemplification. Despite its valuable insights in helping us better understand the pedagogical potential of exemplification to promote episodic learning in science classrooms, it should be noted that our study is not without limitations. One important shortcoming was the scope of our analytical exploration which, as indicated previously, was limited to the pedagogical practices of a single science instructor in a single classroom context (undergraduate course on animal behavior). Additional research will be needed to determine the extent to which similar results can be found in different classroom contexts (topics, disciplines, grade levels, etc.). As emphasized by Lowrie and Ludemann (2015), "the grey area between generals and particulars where imagination and judgement proceed by comparing and contrasting, grouping and regrouping 'cases,' separating out what does not fit some overarching system, calls for further examination" (p. 5). Such an analytical undertaking can reveal ways whereby examples can be more effectively used to help students "think through particulars," to reason inductively and deductively, and hence to learn undergraduate science more meaningfully.

Conclusion

Exemplification is not a panacea for science education, nor is it a pedagogical practice devoid of complications, as commonly assumed. Nonetheless, if effectively and thoughtfully implemented, exemplification can serve as an important source of memorable science learning experiences for students. As our results have shown, how memorable the experience of being given an example is to students depends on a multiplicity of factors, including whether students can relate to the example, how unique and extreme the example is, how much detail is provided, whether the example is enacted rather than told, and whether the example makes students feel sad, surprised, shocked, and/or amused. Rather than simply assuming that all examples are equally effective, careful consideration needs be given to the interplay of all these factors when using exemplification as a means to support science learning.

Awareness of the wide range of design choices and combinations possible is the first step toward pedagogical expertise in exemplification. Such awareness is likely to put biology instructors in a position to more effectively use example-giving as a source of memorability for students. It is our hope that the present study can encourage reflection about this largely overlooked dimension of science teaching and learning and ultimately assist science educators in making more informed use of exemplification in their classrooms.

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