Sources of Affect around Interdisciplinary Sense Making

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Abstract: We unpack an episode in which a case study student in an Introductory Physics for Life Scientists (IPLS) course experiences positive and negative affect coupled to sources of frustration and satisfying resolution. We argue that the positive affect that the student experiences stems from an alignment between his identification as a sense-maker and his epistemological view of this physics course as one that that values sense-making. Conversely, we attribute his frustration to a tension between his identity and his epistemological view of his biology courses as descriptive and fact-driven. We discuss some implications of this model for students engaged in interdisciplinary sense-making more generally. In particular, we suggest that Gavin's frustration with the lack of attention to mechanism in his biology courses might ultimately serve to *strengthen* his sense of interdisciplinary connectedness and satisfaction.

Introduction: Different Reasons for Appreciating Physics

In recent years, efforts have been made to design introductory physics courses that are specifically tailored to life science students (e.g. Meredith & Redish, 2013). A number of objectives are routinely cited for doing so, including the increased importance of physical modeling and quantitative approaches in upper-division biology coursework, the need to train future physicians in methods and technologies developed in the physical sciences, and a general recognition that science disciplines are increasingly integrated and dependent on each other for inspiration and innovation. These objectives often align with national calls for substantial reform of the undergraduate curricula for life science and pre-health profession students (National Research Council, 2003).

In practice, instructors recognize the importance of affect as both a mediator of participation in and an outcome of Introductory Physics for Life Scientists (IPLS) courses. Meeting the interdisciplinary objectives stated above seems to require that students be open to participating in physics. Because life science students often have negative orientations towards physics, helping life science students come to "appreciate" or "like" physics is seen as an important component of interdisciplinary learning. This goal is sometimes made explicit, but more often is conveyed implicitly through efforts to include content that biologists would find "exciting" or of particular "interest." However, the sources and consequences of affective responses have not been well researched.

There are many reasons why life science students might profess to like or appreciate physics. Perhaps, for example, students see utilitarian value in their physics class in preparing them for the MCAT exam or in later coursework. Perhaps students like physics because they find it easy and it makes them feel competent or confident as a learner. Perhaps students like physics because they find it intrinsically satisfying to make sense of why objects behave as they do. These different sources of positive affect can have consequences for how and if students participate in physics and potentially for their participation in other science disciplines. A better understanding of the pathways that lead to affective responses can help instructors be more intentional about the kinds of emotions they are trying to foster in their students.

The focus in this paper is on affective responses that are triggered by moments in which physics is helping a student *make sense* of phenomena previously encountered in his biology courses by seeking coherent mechanistic accounts of these phenomena (Hammer et al., 2005). By focusing on how and why these moments of explanatory coherence generate positive affective response, we hope to suggest ways of inviting students to participate in physics as well as foster an appreciation for thinking and learning across disciplinary boundaries.

In order to better understand both the sources and consequences of affective responses for participation and learning in science, we attend to interactions among affective displays and the ways in which students identify with and understand the epistemologies of the disciplines. We present an episode from an interview conducted with "Gavin," a case-study student in an IPLS course. We examine how aspects of Gavin's identity interact with his epistemological orientation toward physics and biology to generate both positive and negative emotion and unpack the *source* of his affect in these moments. In turn, we consider how this affective response influences and is shaped by epistemological views of coherence in the natural world.

Theoretical and Methodological Approach

In our analysis we attend to an instance in which positive and negative affect are coupled to sources of frustration and resolution. The unit of our analysis is not the individual but rather a series of moments in the context of this interview. We do not claim, for example, that Gavin *always* exhibits these particular emotions for the reasons illustrated by the episode we have chosen. Rather, the episode serves to highlight how Gavin's epistemic resources and ways of positioning his identity were coordinated in these moments. For reasons we describe below, these ways of coordinating epistemology and identity may influence Gavin in the future.

This framework views neither identity, nor epistemology, nor affect as stable entities that an individual carries with him from moment to moment. Instead, each of these dimensions is influenced by the different contexts in which an individual participates (Gupta et al., 2010; Hammer & Elby, 2002; Nasir & Saxe, 2003). This framework does not preclude the possibility that some of these constructs may be more or less consistently activated across a variety of contexts. It simply starts from the assumption that these constructs are sensitive to context and leaves the determination of whether they are more or less stable across context to empirical investigation.

Our focus is on the ways in which an interaction between *identity* and *disciplinary epistemology* is responsible for Gavin's *disciplinary affect* in an interview about his experiences in this IPLS course. Disciplinary epistemology here refers to ways of knowing and learning associated with a particular discipline (Hammer & Elby, 2003). For students, disciplinary epistemologies are likely to be closely tied to their course experiences (Watkins & Elby, 2013). For example, a student might develop an understanding of biology as "complex and difficult to model in a simple way," or of physics as "abstract and idealized" from his biology and physics coursework respectively. Different course experiences could contribute to the development of different sets of epistemological resources. That same student might develop an understanding of biology as elegant and mathematical or physics as uncertain and messy from another set of course experiences.

Identity, like epistemology, is dynamic and context dependent. As Esmonde (2009) writes, "identities may shift in meaning or salience as one moves from one context to the next." The way a student positions herself relative to a discipline can also vary from moment to moment in more or less consistent ways. A student may over time begin to define herself as "a biology person," but may in other moments feel alienated from or excluded from that discipline (Nasir & Saxe, 2003), particularly in comparison to experts. Another student may identify as "someone for whom physics is really difficult," but may, at times, position herself as more aligned with the discipline. There may be ways of identifying that are broader than any particular discipline, but that interact with the individual disciplines in influential ways, such as one's view of himself as "a hands-on kind of person" or "a person who is good with symbols."

Epistemology, identity, and affect are related in various and nuanced ways. Danielak et al. (2013) describe how identity and personal epistemology are coupled for a student who identifies as a certain kind of knower. Disciplinary identity and disciplinary epistemology sometimes evolve together, as when researchers come to position themselves as aligned with or distant from particular disciplinary practices (Osbeck & Nersessian, 2010). Affect, in turn, can stabilize or destabilize epistemic orientations and aspects of identity or may result from a match or mismatch between them. Someone might feel anxious in a context in which his enacted identity is not valued, or proud in a context where it is. At times these constructs of identity, epistemology, and affect reinforce each other, and at times they are in tension. This is particularly true in an interdisciplinary setting in which more than one set of disciplinary identities, epistemologies, and affective responses may be at work.

Gavin's Story: Satisfaction from a Mechanistic Explanation of Diffusion

One goal of our IPLS course is to unpack the physical mechanisms underlying biological phenomena that are only described phenomenologically in typical introductory biology and chemistry courses. An example of this is the diffusion of particles or gases along a concentration gradient, a phenomenon with which life science students become familiar but for which they are often not provided a mechanistic explanation in their introductory courses (Redish & Cooke, 2013).

Gavin finds the unpacking of diffusion in mechanistic terms to be highly satisfying and references the example in describing the role this interdisciplinary course plays in his education more generally:

> [1] Gavin: This [IPLS] class was very good about telling us about thermodynamics and entropy's role in the universe… And I think diffusion was when everything started to click; when we talked about how molecules go from higher concentration to lower concentration because they're bumping into each other so much, and so these Newtonian interactions were able to move particles away from one another… there was less collisions and stuff like that… And so I felt like that's when things started to click [*snaps*

fingers]... I was like that's why molecules go from higher concentration to lower concentration...

[2] Interviewer: So you already knew that it happened?

[3] Gavin: I knew that it happened but then I was like how the hell do they know where the lower concentration is?! And in biology we never explain that [*brushes arm across his chest*]. And I think that biology has done obviously very brilliant things and I love biology, but as far as the professors, they're very knowledgeable but they have to go over so much stuff that they don't really take time to explain why things happen. And I'm a very "why" kind of person; I want to understand why does this happen. And that's why I struggle with [organic chemistry] so much, because it's like 'memorize the mechanisms and take the test' [*throws up his hands*]… well how the hell do I know why the mechanism is happening in the first place?!

[4] Interviewer: How do the molecules know what to do...

[5] Gavin: Exactly. And why do they do this bouncing thing [*moves hands back and forth*] and it was never explained to me very well, and then when I take this [IPLS] class and understand, oh, this is why molecules interact the way they do, this is why you are going to have this expansion of particles over space.

[6] Interviewer: Yeah

[7] Gavin: It's because they collide less often when they're further apart than when they're together. And they are going to want the least colliding orientation which is going have the most microstates which is therefore going to have the greatest entropy.

[8] Interviewer: So it connected... you knew that it wanted the greatest entropy, and it connected sort of underneath it what was causing?

[9] Gavin: Right it gave me a foundation...

[10] Interviewer: And that was satisfying to you?

[11] Gavin: That was very satisfying… understanding the why really gave me the confidence in order to go into tests and be able to rationalize why things work the way they do and what to look for.

In turn [3] of this exchange, Gavin reflects on his experience in prior biology (and organic chemistry) courses. He diagnoses biology as descriptive and fact-driven ("they have to go over so much stuff"), as placing too great of an emphasis on memorization of factual information and too little of an emphasis on the explication of "why things happen." Gavin's epistemological orientation toward biology in this moment is one in which he sees the discipline as failing to take up mechanistic explanations of the sort that his IPLS course provides for diffusion (or perhaps even failing to ask questions for which a mechanistic answer is appropriate). Gavin's reflection on his experiences in biology is accompanied by markers of frustration. He is exasperated that his biology instructors "don't really take time to explain why things happen" and that he is asked to "memorize the mechanism and take the test." In this moment both his words and hand gestures convey frustration. We describe Gavin's frustration as stemming from a disconnect between his identity as a sense-maker – "I am a why kind of person" – and what he finds to be an unsatisfying preoccupation with *knowing* (as opposed to *explaining*) in biology (left side of Figure 1).

Whereas Gavin's epistemological orientation toward biology is in tension with his identification as a "why kind of person," the epistemological view of physics that he articulates in this moment aligns with that identification. Gavin describes physics as a discipline where mechanistic sense-making is commonplace. In turn [1] he credits physics as a place where he came to understand "why reactions proceed the way they do," and in turn [5] as the place where he finally came to understand "why molecules interact the way they do… why you are going to have the expansion of particles over space." In turn [9] he labels the explanatory base he feels he acquired in physics as a "foundation." These descriptions of his epistemological orientation toward physics are accompanied by markers of positive emotion and excitement. He describes his IPLS course in turn [1] as the place where "everything started to click," and in turn [11] agrees with the interviewer that the conceptual foundation that he feels he established is "very satisfying." Where Gavin's epistemological orientation toward biology is in tension with his identification as a "why kind of person," his epistemological view of physics as a place where sense-making happens *aligns* with this identity in such a way that his affective response to physics is notably more positive (right side of Figure 1). Gavin also attributes his greater comfort on tests to improved facility with mechanistic explanation of the sort emphasized in his IPLS course, saying that such an understanding provides "the confidence in order to go into tests and be able to rationalize why things work the way they do."

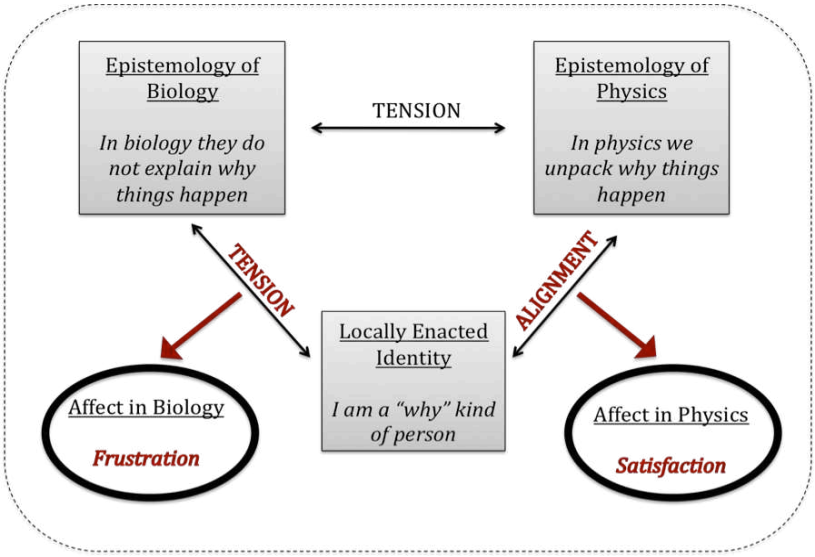

Figure 1. Modeling the sources of Gavin's affect during an interview in IPLS.

Implications for Interdisciplinarity

The frustration stemming from tension between Gavin's self-identification as a "why kind of person" and his epistemological view of biology is coupled to the satisfaction that Gavin achieves in his IPLS course. While we do not know if Gavin would or would not have appreciated physics in its own right had he not first encountered phenomena in biology for which he desired further explanation, his sense of resolution in IPLS *can* be attributed in part to his dissatisfaction with explanations in biology. Gavin positions his satisfaction with the role that physics is playing in his understanding of natural phenomena in direct *comparison with* and in direct *contrast to* his dissatisfaction with the incompleteness of explanations in biology.

Similarly, Gavin's frustration with the lack of attention to mechanistic explanation in his biology courses might actually serve to *strengthen* his ultimate sense of interdisciplinary connectedness and satisfaction. Because he sees *physics* class as a place where he was encouraged to develop explanations, Gavin may actually be more likely in the future to view physics as relevant and important for understanding the living world. The frustration that Gavin feels in association with biology may not only be productive in the sense that it enables him to more fully appreciate and experience the power of mechanistic explanation when he does eventually encounter it, but also in the sense that it allows him to appreciate a role that physics can play in the life sciences. A student who is never troubled by a lack of mechanistic reasoning in biology (or a student who sees biology as descriptive but actually *likes* that aspect of the discipline) might see superficial connections between biology and physics in an IPLS setting, but that student is less likely to see physical models as *essential* for answering some interesting questions in biology.

Figure 1 represents disciplinary affect as an *outcome* of the interaction (either tension or alignment) between identity and disciplinary epistemology. It is also plausible, however, that the alignment between Gavin's identification as a why kind of person and his disciplinary epistemology is *stabilized by* the positive emotions resulting from that alignment. The feelings may reinforce Gavin's belief that he is a sense-maker who values mechanistic explanation, and it is not unreasonable to predict that he may seek out opportunities in his future courses to do more of that sense making. We would hope, for example, that Gavin might begin to look for opportunities to make sense of biological phenomena in mechanistic ways that are authentic to the discipline of biology. Alternatively, if Gavin does not have this kind of opportunity in his subsequent life science courses, he might consider leaving biology for a field that he views as more conducive to mechanistic sense making (Danielak et al., 2013). By way of comparison, an IPLS student who experiences neither Gavin's frustration with biology nor his satisfaction in having explained something important in his physics course may be less likely to seek out connections between physics and biology beyond the confines of the IPLS environment.

In a course that has as one of its goals the dismantling of disciplinary silos, positive affect associated with the role that physics can play in unpacking biological phenomena is of particular importance. Future work is required to establish whether such affect indeed does stabilize a student's orientation toward interdisciplinary sense making, and to determine if such affect makes it more likely that that student will cross disciplinary boundaries in the future. But the positive affect is also an end *in and of itself*. Many prominent scientists have attributed their motivation to participate in science to those rare but powerful feelings of satisfaction, pleasure, and beauty that accompany the successful reconciliation of various pieces of conceptual understanding. It is possible for our students to experience similar satisfaction. When defining what it is that we hope our students will learn in interdisciplinary courses, we would be well served to consider also what we hope they might *feel*.

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