Tracing Literate Activity across Physics and Chemistry: Toward Embodied Histories of Disciplinary Knowing, Writing, and Becoming[1]

Bruce Kovanen, University of Illinois Urbana-Champaign
Nicole Turnipseed, University of Denver
Megan Mericle, University of Illinois Urbana-Champaign
Kevin Roozen, University of Central Florida

Abstract: Scholarship animating both WAC/WID (Allan, 2013; Gere, et al., 2018; Hendrickson, 2016; Kells, 2007; Reid, et al., 2016) and STEM (Roth, 2003; Roth & Jornet, 2013; Tsui, 2007) has increasingly called for pedagogical attention to learners' lived, embodied experiences of knowing, writing, and becoming in and across disciplinary worlds. As one response to such calls, this article argues for "literate activity" (Durst, 2019; Prior, 1998, 2015; Prior & Shipka, 2003) as a productive approach to addressing people's embodied engagements with semiosis in unfolding moments that are historically dispersed across people, tools, times, and places. To illustrate what attention to literate activity offers for understanding writing and learning, we present analyses of learners' embodied actions across an array of semiotic resources including texts, talk, images, and gestures for two different STEM settings: physics and organic chemistry. In addition to foregrounding the wealth and variety of semiotic modalities that mediate students' embodied engagement with disciplinary science, our analyses illuminate the extended histories of semiotic activity that learners continually build as they fashion disciplinary ways of knowing, writing, and becoming.

Scholarship in both WAC/WID and STEM has recently been increasingly animated by calls for pedagogical attention to the diversity of learners' communicative repertoires and pathways of disciplinary development. Alert to the historical, relational, and embodied ways of being shaping how learners co-create their communicative lives and worlds, both in school and beyond it, WAC/WID scholarship has increasingly worked toward developing what Elizabeth Allan (2013) refers to as "a more nuanced understanding" of disciplinary writing that "can inform our interpretations of unfamiliar communication strategies and clarify our approaches to teaching" (pp. 2-3). One central line of inquiry has focused on multimodality, particularly in relation to programmatic structures and pedagogical practices encouraging learners' use of multiple communicative modes in their disciplinary and interdisciplinary writing (Gere, et al., 2018; Reid et al., 2016). The proliferation of scholar-practitioners involved in and affected by the Writing Across Communities (WAC[2]) initiative at the University of New Mexico (UNM), spurred by the work of Michelle Hall Kells and others, continues to extend notions of what ecological spheres WAC can and should affect. Kells (2007) writes, "Models that fail to connect the dimensions of human interaction with local and global environments obscure the interdependence and interrelationships integral to community development and

survival" (p. 97). In practice, taking up this ecologically connected focus, WAC[2] practitioners encourage students to integrate the repertoires of linguistic and cultural practices they call on regularly in their communities of belonging with those they are building in the classroom to affect the personal and public spheres integral to their own and their communities' lives. Juan Guerra's (2008) notion of transcultural citizenship, offered in response to increasing educational calls for preparing global citizens,

> provides a more effective way for educators to remind our students—especially students from historically marginalized communities—that they can and should make use of the prior knowledge and experiences they have accumulated and the rhetorical agility they have developed in the course of negotiating their way across the various communities of practice to which they currently belong, have belonged, and will belong in the future. (p. 299)

These and other WAC initiatives offer practical ways forward for educators concerned with supporting the rhetorical dexterity at the heart of transcultural citizenship. However, as Brian Hendrickson (2016) has argued:

> Institutions of postsecondary education, and the field of writing across the curriculum and in the disciplines (WAC/WID) in particular, need to do more to trouble learning paradigms that employ writing only in service to particular disciplines, only in traditional learning environments, and only in particular languages, or in service to an overly narrow or generalized idea of who students are, where they're going, and what they need to get there. (p. 1)

Likewise, STEM scholarship has also addressed embodied communicative resources and practices that shape students' access to and support in STEM. Addressing the ways that scientific practice is not merely about "producing and manipulating arbitrary symbolic inscriptions that bear abstract, universal truisms untainted by human corporeality" (p. 358), Dor Abramson and Robb Lindgren (2014) argue for an understanding of mathematics,

> and in fact all STEM content, as grounded not in its sign systems and inscriptional forms (which clearly are pivotal to its practice) but in the situated, spatial-dynamical, and somatic phenomenology of the person who is engaging in activity marked by society as 'mathematical.' (p. 358)

More broadly, recent scholarship has attended to issues of gender, ethnic, and racial diversity in STEM. Of course, diversity issues in STEM are structural, social, and historical. As Lisa Tsui (2007) writes,

> The disproportionately low participation of African Americans, Native Americans, and Latinos in STEM fields is attributable to a number of factors, including barriers that are of a cultural (social expectations for different groups), structural (historical laws and regulations that barred the entry of minorities into education and employment), and institutional nature (discriminatory policies and practices). While societal transformations have reduced formal and legally sanctioned barriers, the lineage of accumulated deficit opportunities within a socially stratified society continues to exert its negative impact. (p. 555)

There is also growing recognition that administrative approaches to recruitment and retention cannot create sufficient change. Bringing into the equation pedagogical approaches to supporting students' experiences, Tsui (2007) warns against reforms in STEM education that "assume that what is recommended for the general STEM student body is necessarily what works best for those who are underrepresented in that population" (p. 555). This mantel has been taken up by scholars including Mary Moriarty's (2007)

attention to the uptake of inclusive STEM teaching and Aída Guhlincozzi and Julia Cisneros' (2022) examination of institutional constraints to STEM diversity efforts.

As one response to this special issue's invitation to generate further conversation between WAC/WID and STEM scholarship regarding disciplinary writing and learning, we argue for WAC/WID and STEM scholars and practitioners taking up "literate activity" as a productive conceptual lens for addressing the richness and complexity of learners' lived, embodied experiences making meaning in, across, and beyond disciplinary worlds, both in terms of the rich variety of semiotic resources learners employ across emergent moments of activity and the lengthy histories of action and agency that flow into and emanate from their disciplinary engagements. We believe literate activity offers a capacious perspective that can engender pedagogical approaches in both WAC and STEM that value and support the rich communicative repertoires students bring to, and build through, their disciplinary studies in ways that are meaningful to the multiple communities they participate in.

Attending to Literate Activity

Drawing on the work of Paul Prior (1998, 2014, 2015; see also Prior & Shipka, 2003), we argue for literate activity as a productive approach to conceptualizing writing, learning, and socialization across disciplines and contexts. In *Writing/Disciplinarity*, Prior (1998) forwarded literate activity as a unit of analysis that could better account for the rich variety of communicative resources, practices, and activities entangled throughout people's engagements with what are typically referred to as "writing" and "reading." Defining literate activity "not as located *in* acts of reading and writing, but *as* cultural forms of life saturated with textuality, that is strongly motivated and mediated by texts" (p. 138), Prior's notion of literate activity emphasizes the wealth of communicative practices at play in people's meaning making and shows how their embodied engagement with such practices is woven into and across histories of action.

First, literate activity pushes us to consider people's embodied engagement with a rich variety of semiotic resources and modalities (e.g., ways of acting with spoken and written languages, images, gestures, movements, and sounds). Prior's purposeful use of the terms "textuality" and "texts" explicitly signals the incredible diversity of semiotic tools that mediate communicative action, how writing routinely involves constellations of "talk, text, bodily stance and gesture, graphics, mathematics, and other symbolic activity woven together through interactional history" (1998, p. 70). Literate activity, then, provides a way to move beyond reductive conceptions of the kinds of representational practices typically associated with "writing" and "reading" in order to more fully address the historically unfolding tangle of multiple semiotics described by Prior and Stephen Thorne (2014): "talk, embodied action and gesture, visual design, observation and manipulation of material and virtual objects, inner semiotics of thinking, feeling, and attention" (p. 37). In addition to the historical blending of multiple semiotics, literate activity also calls attention to people's lived, embodied engagement with those resources in the world, to people's gesture and bodily motion involved in textual activity as well as the affective and emotional dimensions acting with texts entails. To overlook the embodied nature of textual meaning-making is to erase people from literate action. The result, as Sarah Durst (2019) argues, is that "we end up with decontextualized, disembodied practices that offer little in the way of understanding how and why people's literate activity works for them throughout their lifeworlds" (p. 473).

Secondly, literate activity calls us to attend to how people's engagements with an array of semiotic resources are entangled along historical trajectories of meaning-making. For Prior, people's embodied engagements with semiotic tools and representations are not located in discrete, autonomous moments, but rather along far-flung histories of action that reach across people's near and distant pasts and futures. Each moment of literate action, Prior (1998) notes, "implicates multiple activities, weaves together histories, and exists within the […] networks of lifeworlds where boundaries of time and space are highly permeable" (p. 277). As such, people's literate activities emerge not just in response to the demands of the here and now, but also from

the historical flow of people's experiences across many other thens and theres. Prior (2018) argues that attention to literate activity is central for understanding what he refers to as people's "trajectories of semiotic becoming" (Introduction), the continually emergent, richly embodied, complexly semiotically mediated, and heterogeneously dispersed pathways along which people develop throughout their lifespans and across their lifeworlds. In contrast to models that would situate development within single homogeneous settings and single semiotic modes, Prior (2018) writes that becoming emerges "where discourses and knowledge are necessarily heterogeneous, and where multiple semiotic resources are so deeply entangled that distinct modes simply don't make sense" (Conclusions). In contrast to narrow, static models that cast learning and socialization in terms of singular literacy skills or linear development within and along pre-fabricated channels toward pre-determined endpoints, *becoming* foregrounds the continual, open-ended, holistic nature of human development of the whole person across multiple lifeworlds. "Becoming," Prior (2018) writes, "is entangled complexly, materially, historically: it calls on us to abandon narrow notions that seek to fit people into narrow curricular imaginings and instead find ways to nurture diverse developmental pathways" (Conclusions).

As a perspective for understanding writing and learning in WAC/WID and STEM, then, a focus on literate activity highlights the wide array of semiotic practices people employ as they make meaning across multiple timescales of action. Ultimately, literate activity illuminates people's textual action as "not only a process whereby texts are produced, exchanged, and used, but also part of a continuous sociohistoric process in which persons, artifacts, practices, institutions, and communities are being formed and reformed" (Prior, 1998, p. 139).

In the sections that follow, we offer two vignettes from case studies of undergraduates' disciplinary literate activity. Drawn from Bruce's situated study of lab report writing, the first vignette focuses on students in a physics course, examining their orchestrations of talk, written language, objects, gesture and bodily movement, and data inscriptions (print and digital) across multiple moments of their collaborative lab work. This analysis illuminates the embodied semiotic activity animating physics students' learning and writing that can easily be overlooked without attention to the diversity of communicative resources that are woven and rewoven across even brief spans of time. Drawn from Kevin's longitudinal case study of Samuel, a microbiology major, the second vignette elaborates how Samuel's embodied engagements with scientific diagrams for an organic chemistry class weave together his experiences with religious worship and his investment with science in ways that have long-term consequences for his disciplinary knowledge and identity. This analysis foregrounds the richly embodied semiotic practices shaping students' learning that can easily be occluded without attention to the variety of representational practices people act with and the enduring consequences they have for knowing and becoming. Together, these case studies reveal the richly semiotic histories that weave across a few minutes in a physics lab and of a lifetime of engagement with religion and science. When we expand our attention beyond people's engagements with any single semiotic modality and any single community to view disciplinary enculturation as involving multiple histories reaching across the lifespan, what comes into view are richer, more complex maps of writing and learning that surface the semiotic practices students bring to and develop in disciplinary spaces and the long-term implications they hold for students' lives across multiple communities. Making these practices more readily visible, we hope, will allow both students and teachers to better see, value, and stoke the various community-based repertoires they bring to and carry forward from their disciplinary work. For WAC and STEM practitioners, such knowledge can support the design of pedagogies that better account for students' diverse practices and communicative contexts, as we will discuss in more detail in the conclusion.
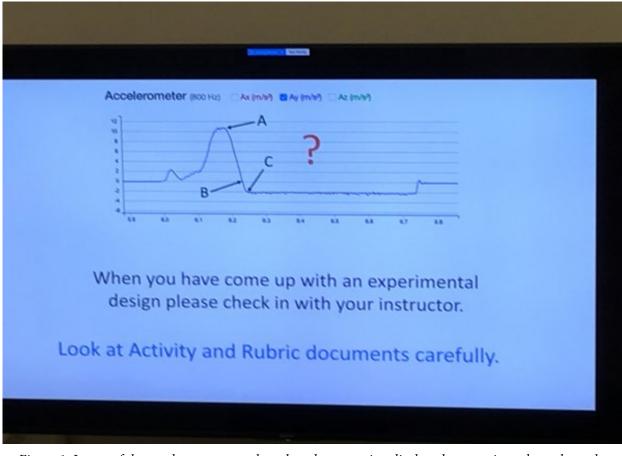
Examining Literate Activity across a Physics Lab

The research informing this vignette was undertaken as part of "Writing Across Engineering and Science" (WAES), a writing-across-the-curriculum initiative employing a transdisciplinary action research framework (Stokols, 2006) to improve writing instruction across STEM (Gallagher et al., 2020; Ware et al.,

2019). Bruce began working with the course instructor to examine student collaboration in a newly-developed, inquiry-focused instructional lab environment (See Ansell, 2020 for curricular design). The data presented here is drawn from that work, which involved two semesters of data collection that included 10 hours of video- and audio-recording of laboratory interactions, 200 lab reports, and rubric feedback. The analysis of these data is driven by the following research question: How do students' literate activities mediate their cooperation in the completion of a lab report?

The weekly lab session activities focused on students using a piece of laboratory equipment: the Interactive Online Lab (IOLab), which is a handheld device with sensors that measure light, acceleration, magnetic fields, electrical signals, frequency, and more. Students decide which sensors to engage during experiments. These weekly sessions provide students opportunities to "practice confronting and making decisions" (Ansell, 2020, p. 25) as they design their own experiments using the IOLab, generate and interpret data from the IOLab, and then compose lab reports describing their findings.

Early in the semester, students are presented with an accelerometer graph (see Figure 1) of the result of the IOLab being pushed across a tabletop. Working in groups, the students must determine which point on the accelerometer graph (point A, B, or C) indicates when the hand pushing the IOLab has stopped touching the device. To accomplish this task, students must use their IOLab to generate data that will allow them to answer this question. In the previous lab, students developed familiarity with the wheel and accelerometer on the IOLab by testing acceleration on various inclines, and this lab session deepens that familiarity with collecting and interpreting data from the IOLab.

Figure 1: Image of the accelerometer graph and student question displayed on monitors throughout the room.

We pick up the action about 24 minutes into the lab session focusing on one group of students. In this group (a trio of white students, Yuri, James, and Conrad,[2] from left to right) have determined that point A is not the answer and are debating whether their answer should be B (when acceleration is at 0) or C (when acceleration is negative). In order to decide between point B and point C, the students push their IOLab across the tabletop and examine the data generated by the IOLab's sensors.
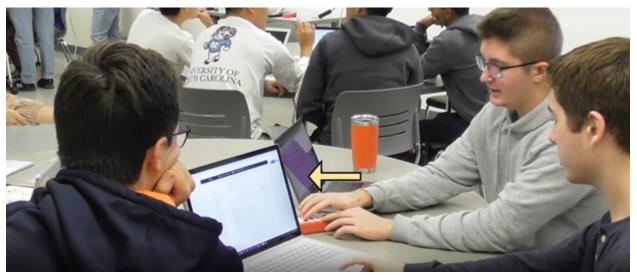

Figure 2: *Conrad demonstrates the group's pushing method with index and middle finger pushing the IOLab.*

As they examine the data they've collected from their initial trials displayed on James's laptop, he remarks, "This looks fairly convincing for B." In response, Conrad says, "Yeah I know it does…Because like yeah we are accelerating it right when we let go. It's moving from acceleration to deceleration." As he says "accelerating," Conrad moves the IOLab forward with his index and middle fingers to demonstrate (see Figure 2). Then, Conrad turns to James and explains, "So it's like we're hitting that peak." As he says this, he raises his arm and hand in an arcing motion that replicates the accelerometer data shown on James's laptop (see Figure 3).
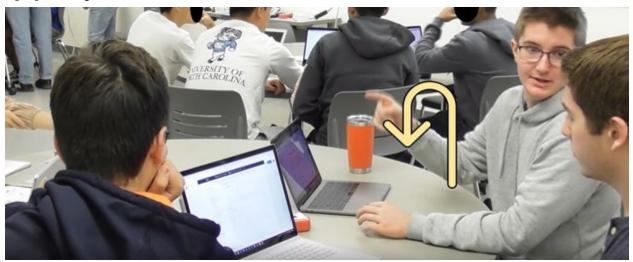

Figure 3: *Conrad traces the accelerometer graph from Figure 1 with his hand.*

After Conrad's explanation, James nods, and Yuri says, in reference to the data represented on James' screen: "Throw that in there," which prompts James to take a screenshot of their data to upload to their Google Doc while Conrad types the following:

> We are finding out at what point on the accelerometer graph we let go of the IOLab. We believe that it will be at the point when acceleration turns zero, meaning we release the device, which it is moving from positive to negative acceleration (a peak), which means that the acceleration would be 0.

In two sentences, talk, gesture, and data are remediated into textual form. By tracing how this paragraph emerges from students' literate activity, we can attend to the wealth of semiotic resources at play in these situated actions and foreground how fluidly the students move among them, and, especially, entangle them. In just a few sentences, we can trace the convergence of conversation, gestures, diagrams, graphs, and the movement of the IOLab into textual forms and how, at the same time, the other students are taking screenshots of their data and formatting them to fit into their Google Doc lab report.

In these moments, representations are transformed as they are distributed across students' embodied actions. By tracing the relative durability of such actions as they are remediated, like how Conrad's gesture of "a peak" is first drawn from representations of data displayed throughout the classroom, then represents their collected data, and is further remediated into textual forms as an explanation for the group's decision-making process, we can see how literate activity animating the lab report implicates a wider variety of semiotic resources rather than just words on a page. By approaching the creation of a lab report with literate activity as a framework, we can trace how students transform and remediate representations as they develop interpretations of their data. In this example, Conrad's gesture enlivens the graphical events provided by the IOLab's accelerometer, drawing a connection between the group's actions and a representation of their data to develop a shared understanding and an interpretation of their data and its accompanying graphical output that is subsequently transformed into lab report prose.

Having determined that point B (when acceleration = 0) indicates the point on the accelerometer graph when their hand is removed from the IOLab, the students turn to their next objective: remediating their findings into mathematical expressions. As they huddle around James' laptop, which is displaying their data, Conrad gestures towards their data and asks: "How do you mathematically show this?" Conrad's question is prompted by the next section of their lab report where they must produce another representation of the answer they have decided upon. In other words, while they have offered an interpretation and representation of their answer in text (the two sentences reproduced above), they also need to produce a mathematical expression that explains their answer. Yuri is unsure about whether the mathematical expression is necessary and says, "You don't," but James responds, "Kind of like our last lab, what was our last lab?" Yuri prompts the group to "Look at the rubric" as James pulls up their previous lab reports. James shifts rapidly between a variety of documents—their current lab report, the rubric, and assignment sheet for the lab period—before opening the previous week's lab report on acceleration and inclines, which included a free body diagram, a representation common in physics and engineering that visualizes how forces act on an object. When the images from their previous lab report arrive on the screen, the students erupt in a chorus of "yeahs." Yuri drives the consensus and says, "That's how you do it…free body diagram" and picks up a marker and begins to draw on a whiteboard. As he draws, James inserts screenshots of their data to the lab report, and Conrad begins to write the results section. As he completes the free body diagrams, Yuri takes pictures of the diagrams with his smartphone and adds them to the group's report; James and Conrad then resize and caption the photographs, as represented in Figure 4.

Figure 4: Force diagrams from the students' lab report, one including the force of the push (on the left, captioned "When pushing IOLab" by students) and one without (on the right, captioned "After we release the IOLab" by the students).

Informed by a literate activity perspective, this analysis traces—even across just a few minutes of video-recorded data—a wealth of activity implicating an array of semiotic resources such as gesture, talk, graphing, photography, drawing, composing in a shared Google Doc, and managing multiple texts (reading and referring back to other documents like the rubric and previous lab reports). This perspective pushes us to attend more closely to "events of semiosis in which writing is implicated" (Prior, 2015, p. 197), to go far beyond considering only iterations of texts and rubric responses as relevant moments in learners' meaning making and to recognize the embodied and historical chains of semiotic remediation (Iedema, 2001; Prior, 2010) that students act with.

Examining Literate Activity across Organic Chemistry

The research informing this vignette was undertaken as one of a series of longitudinal qualitative case studies examining the literate activities shaping undergraduates' engagements with disciplinary science (e.g., engineering, microbiology, medicine). The data that Kevin presents here emerged from a study focused on Samuel, a Black (his chosen term) microbiology major at a large public university pursuing a career in veterinary medicine. Data collection for the study included eight formal interviews over a period of three years, which resulted in approximately 14 hours of video- and audiotape data, as well as collection of texts and artifacts. The analysis of this subset of data is driven by the following research question: What literate activities mediate learners' engagement with disciplinary science? What are the long-term impacts of learners' participation with such literate activity?
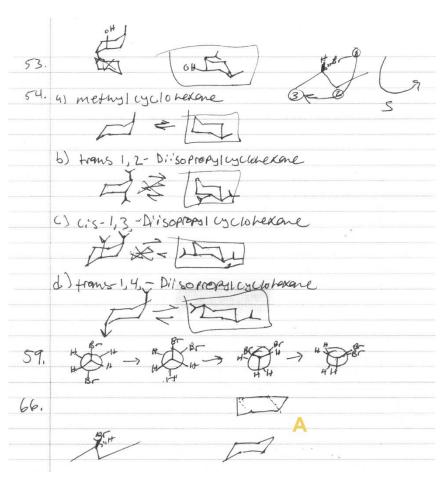
As an undergraduate, Samuel's experience was initially textured by the tension he felt between his intense interest in science and his long history of engagement with religious worship. According to Samuel, his fascination with science began with the inquisitive nature he displayed as a child. As he described it, "growing up I always had a love for animals and I was always the thinker, always asked a bunch of questions." He noted, though, that "growing up in the area I grew up in, it wasn't cool to really pursue that, so like in my science classes, I really wasn't that interested in that." Through his volunteer work with a pet care center and his experiences in labs for his high school science classes, Samuel grew increasingly drawn to "just finding out how something works at the atomic level and molecular level and cellular and the tissue, organs, developing into the organism and how all of that works." By the middle of high school, Samuel indicated that he "just fell in love with biology. I was able to immerse myself in it. And I'm like, 'I'm really good at this'." His experiences with animals eventually drew him toward college in pursuit of a career in veterinary medicine.

The one thing that gave Samuel serious pause about pursuing study and work as a scientist was the impact it might have on his deep engagement with the church, a vital part of his upbringing and family life. Members of Samuel's family were active in the Black Presbyterian church they have attended for generations. Both of his parents held positions in the church leadership, and Samuel and his brother had been involved with church activities since their early childhood. Recalling the tension he felt about maintaining his faith and presence in the church as his budding interest in science grew, Samuel stated,

> When I first started really pursuing science, I had trouble trying to see science and God in the same vein because of the way our culture works. We see them as two polarized, very opposite entities, that you can't pursue knowledge of the world or try to understand creation and God himself. […] All of the people that I would talk to would be like either, "Yes! Science is the answer, science is the way, science gives me all of the answers that I could ever possibly need to know." And then others were like, "No, science is not this. You can't believe that all of this makes sense."

Faced with the dichotomy offered by this powerful cultural narrative, Samuel considered forsaking his interest in science for what he described as a "steady job" that would allow him to stay actively involved in his church. At the point Samuel started college, he had shifted toward a different stance, reconciling himself to pursuing a career as a veterinarian while keeping his religious engagement fairly private.

From the very beginning of his organic chemistry course, Samuel was immersed in acting with a rich orchestration of semiotic resources across a wealth of modalities. His descriptions of his activities for the course routinely mentioned his engagement with "interpretive journeys," a term Elinor Ochs, Sally Jacoby, and Patrick Gonzalez (1994, p. 158) use to describe scientists' practices of generating visual images and embodily animating them "verbally, gesturally, and graphically" to transform them into richly discursive spaces. Acting with visual diagrams played an especially prominent role in his work for the class. Much of the activity centered around encounters with a variety of molecular diagrams, bare-bones graphic depictions that make visible a molecule's relevant features and its spatial

Figure 5: A page of Samuel's organic chemistry notes.

arrangement (like those shown on the page from Samuel's organic chemistry notebook offered in Figure 5). The molecular diagrams were interwoven with spoken and written language, numbers, gestures, and other kinds of visual representations.

Describing a typical class lecture, for example, Samuel indicated that his professor "doesn't write too, too much on the board unless it's drawing a structure. […] Like a Newman projection, she'll draw that on the board. Like an organic structure she may draw on the board and then talk about chirality of a compound."

Samuel indicated that he was somewhat surprised at the emphasis placed on being able to draw the diagrams, saying:

> I don't write very neatly and I don't draw very well. So the fact that I had to draw these chair conformations [the diagrams in Figure 5 with the boxes drawn around them] in pen is just weird. Plus, like, one example of drawing them, like learning how do it […] She [Samuel's organic chemistry professor] taught us to set up each of these. [Samuel picks up a pen and draws the two chair conformation diagrams labeled 'A' at the very bottom right-hand side of the page shown in Figure 5]. Draw 2 parallel lines, set them each apart, and then draw an equilateral triangle. Well, whenever I would do it like that, my chair conformations would come out looking like this [laughing, and pointing to the top conformation diagram he drew at the bottom of the page]. And I'm like, I don't understand! […] So I learned, okay if I do this and draw this up and draw this down, just do dramatic everything, then it comes out looking like a chair conformation [drawing the chair conformation diagram at the very bottom right-hand side of the page].

In this portion from the interview, Samuel describes and illustrates two different techniques he has encountered for drawing chair conformation diagrams. The first strategy, shown to him by his professor, involves drawing two slightly offset parallel lines and connecting them with two equilateral triangles. His comments regarding the second strategy suggest that it is a version of the first technique, but involves drawing sharper, more "dramatic" triangles. Despite their mundane and practical nature, these visual diagrams allow Samuel to re-represent molecules that can't be seen with the naked eye, and that are too messy and complex to make out even when made visible by modern imaging technologies. These diagrams afford him a way of understanding how bonds are likely to change in response to interactions with other molecules, or how easily bonds might be formed or broken.

While acting with scientific diagrams certainly allowed Samuel to see the key features of molecules, they also allowed him to see a great deal more. For Samuel, whose life experiences include a deep and sustained engagement with religious worship, his ability to see, use, and construe scientific diagrams was deeply historied with, and thus shaped by, his engagement with his faith. Over multiple interviews, Samuel routinely mentioned how these visual renderings illuminated God's handiwork to him. His heterogeneous perspective of chemical diagrams surfaced quite unexpectedly, for example, while we discussed some of the Bible passages he was working to memorize. Included below is an excerpt from an interview focused on a passage from Colossians:

> Samuel: So Colossians 1:17, [reading from an index card with Colossians 1:17 written on it] "He is before all things and in him all things hold together." […] There's nothing apart from him, literally nothing apart from him because everything, institutions, atoms, subatomic particles, everything holds together in Christ.
>
> Kevin: I can see why you chose that one.

> Samuel: And then when people ask me why I believe what I believe or why I think the way I think I say, "Hey, well, here's what the Bible tells me and it actually makes a lot of sense when you study like chemistry, we learn how the trend for the universe is randomness but the very nature of matter, even at the most seemingly insignificant of levels, the microscopic levels, there's organization. There's organization that we can actually notice plus there's still things that we don't understand about the organization and the structure of an atom, of the nucleus, of orbitals or electrons. We can't tell with any true 100% certainty where an electron is around an atom in orbit. And that becomes increasingly difficult when we talk about hybridization and the bonding that occurs between an SP3 orbital and an SP3 orbital like in ethane."

After reading the verse, Samuel elaborates the phrase "all things hold together" by emphasizing that "all things" encompasses "institutions, atoms, and subatomic particles." Following Kevin's brief comment about Samuel's decision to choose Colossians 1:17, Samuel then indicates that everything being held together by a divine maker is consistent with what the study of chemistry has illuminated regarding the ordered design of even the smallest levels of organization for the physical world. As examples, he evokes the structure of the atom and its constituents and the bonds between the carbon atoms in a molecule of ethane, structures typically represented in the diagrams he would have encountered during lectures for his science courses, on the pages of his course textbook, and those he accessed online. For Samuel, the organization and order "at the microscopic levels" made visible by diagrams depicting the SP3 bonding in ethane evidence God's ability to "hold all things together."

When viewed through the lens of literate activity, Prior (1998) asserts that disciplinary writing and learning emerge as "very human moments, in which hybrid actions and understandings weave together personal, interpersonal, artifactual, institutional, and sociocultural as well as disciplinary histories" (p. xii). This perspective illuminates how Samuel's embodied engagements with visual diagrams entangle his experience of disciplinary science with his long history with religious worship. As a result of that interweaving, Samuel's understanding and use of such diagrams for his science courses is supported by his engagement with the Black church that has figured so prominently in his life. A number of scholars (Brandt, 2001; Moss, 1994, 2002) have documented the ways the Black church sponsors its members' literacy practices in powerful and long-lasting ways, particularly in terms of supporting an orientation toward literate practice which affords "a multiplicity and simultaneity to the meanings of literacy—a synergy that often combines practical and spiritual significance and that makes one meaning less compelling without the other" (Brandt, 2001, p. 123). Samuel's encounters with visual inscriptions created a space where he could weave science and faith together in ways that simultaneously deepened and enriched his knowledge of and enthusiasm for both science and religion.

Samuel's interweavings of science and religion do not just lead brief, fleeting half-lives in the flow of his history; rather, they held enduring consequences for his extended becoming as a scientist-in-the-making. Consider, for example, Samuel's descriptions of his encounters with visual diagrams in his undergraduate honors thesis, which he wrote during his final year of college. To fulfil his senior thesis requirement, Samuel chose to explore how historical figures, including Galileo and Jonathan Edwards, navigated the seeming disjunctures between science and faith. As part of his research, he also included some of his own experiences navigating the relationship between science and faith over his college years. In contrast to the dominant cultural narrative that understands science and faith as "mutually exclusive or at the very least thought to operate in vastly different spheres such that one ought not to influence the other," as he described it in his thesis, by Samuel's senior year of college he had come to recognize that,

> the relationship between science and faith seems to be a synergistic one: the two enhance one another. As individuals study both the book of nature and the book of scripture, their love of God and enthusiasm for science are both enhanced.

In the opening portion of his thesis, Samuel indicates that he arrived at his conclusion based on his observations that science and faith had come together in a number of ways throughout his life as an undergraduate. Reflecting on the past four years, in his introductory chapter Samuel writes,

> As I began to grow in my knowledge of God and the Scriptures, I was also growing in my knowledge of biology and chemistry. […] As I studied science more deeply, He [God] seemed more fascinating, more brilliant, and more beautiful than I first realized. This, in turn, made me want to study science even more so that I could see more of the awesomeness of God.

Over the next thirty-nine pages of his thesis, Samuel points to a number of particular instances in which science and faith had come to be entangled in his life, each of which involved his close encounters with visual representations. For example, in one passage where he reflects on his introductory science courses from his freshman year, Samuel wrote,

> By viewing science in light of the sovereignty of God, I grew increasingly fond of Him and His creative genius. In each of my biology and chemistry courses, the incredible complexity and intricacy of the various systems that allow living beings, animals and microbes alike, to function left me in an incredible state of awe. Far too often I would find it rather difficult to contain my elation as my professors outlined these systems in great detail. Many times these observations simply made sense in light of the Character of God as expressed through the Scriptures.

In this passage, Samuel indicates that it was the "incredible complexity and intricacy of the various systems that allow living beings, animals and microbes alike, to function," presented to his eye through the many inscriptions in his biology and chemistry classes, that provided him with a view of "the Character of God." For Samuel, viewing "science in light of the sovereignty of God" not only helped him make sense of the complex systems represented in his lectures and textbooks, but also enhanced his appreciation for "His creative genius."

Judging from the numerous instances Samuel describes throughout his thesis, his encounters with diagrams held some enduring consequences for Samuel's becoming as a scientist-in-the-making. The interweaving of science and religion was not just something he did initially in his early science courses that eventually subsided as he progressed through the curriculum. Nor was it something that faded as his participation with science deepened. Rather, it increasingly intensified. Over four years, Samuel's encounters with diagrams deepened and enriched not just his knowledge of science and religion, but also the affective intensities that motivated him to know more about them. The entangling of science and religion would continue as Samuel navigated four years of veterinary school, during which he led a large weekly Bible study for members of his cohort, co-facilitated a smaller Bible study as his schedule allowed, and interacted with the Christian veterinary organizations on his campus. Samuel graduated from veterinary school in Spring 2018 and quickly started work as a veterinarian in a large city in the same region as his hometown. He also joined and became an active member of one of the nearby churches, and has continued his participation with the religiously affiliated veterinary medicine organizations at his alma mater.

As Sarah Durst (2019) notes, from a literate activity perspective, disciplinary practices and identities emerge from "the lamination of complex histories, presents, and futures—the myriad threads of people's lives" (p. 476). For Samuel, his embodied encounters with visual diagrams in his science coursework over multiple years of his undergraduate and then graduate education occasioned a discursive space which allowed him to weave his histories with religion and science together in ways that allowed him to assemble an identity for himself as a scientist-of-faith. In addition to creating moments when he could participate in both religion and science in agentive ways, Samuel's encounters with diagrams also allowed him to draw his past into his continually emerging present to fashion a future for himself as a veterinarian and congregant.

Implications for WAC Mentoring and Pedagogy

Addressing what the future holds for understanding and supporting disciplinary writing and learning, Chris Anson (2016) articulates a need for faculty across the university "to move into much deeper considerations of pedagogy than designing effective assignments and creating clear evaluation criteria" (p. 542). "Faculty in all disciplines," Anson asserts, could benefit from "understanding much deeper and more challenging ideas about interrelationships between students' existing knowledge or experience and the nature, constraints, and activity systems of the writing they are asked […] to produce" (pp. 542-543). Based on the accounts we offer above, we argue that attention to literate activity—to the wealth and variety of semiotic resources people act with and the way those resources are woven into and propel the histories of meaning-making that people assemble across moments and lives—is essential for developing rich, capacious perspectives of disciplinary practices and identities that can serve as the foundation for designing pedagogical opportunities that more equitably and responsively support the historical becoming of people, their practices of knowing, and the disciplinary worlds they are continually (re)fashioning in ways that are meaningful to themselves and their communities.

Accounts like the ones we offer above are central to the WAES transdisciplinary action approach (Ware et al., 2019) to curricular change, as they provide the project team composed of faculty and graduate students from both writing studies and disciplines across STEM with a mentoring framework for developing a deeper, richer, more complex understanding of the deeply embodied semiotic work inherent in STEM writing and learning and how it can shape potential pathways for students' disciplinary becoming. Bruce's analysis of the far-flung orchestrations of semiotic resources students leverage in the process of conducting their lab work and assembling their lab report, for example, push the project team to attend to semiotic domains beyond text as relevant grounds for WAC work. In incorporating such accounts into WAC mentoring, WAES works to support the development of diverse ways of doing and being in the world from which disciplinary writing and learning come to emerge throughout learners' lives.

In addition to informing frameworks for WAC mentoring, accounts of disciplinary writing, knowing, and becoming like the ones offered here can lead to pedagogical approaches aimed at making visible the diversity of communicative resources learners bring to the university and that they use to reach across, and thus weave together, the seemingly disparate social worlds of disciplines and communities. Kevin's analysis of the semiotic ensembles at play in Samuel's engagement with organic chemistry and how they shape his becoming as a scientist-of-faith (see also Durst, 2019; Prior, 2018; Roozen, 2020 for extended accounts of STEM literate activity that reach across people's lifeworlds), for example, have motivated him to develop opportunities for the students in his classes to examine their own disciplinary practices, identities, and pathways through the lens of literate activity. Students' responses offer insightful accounts of their lived experiences with the wide variety of communicative resources that have shaped their histories of participation with STEM. In one example, Dan Remie (2019), an aerospace engineering major, traced the trajectory of literate activities that shaped the pace and path of his history of involvement with astronomy, a pathway that weaves a wealth of semiotic resources, including print and digital encounters with written language and visual images, through his experiences with science classes in school, self-sponsored journaling, and writing to a pen-pal.

Ultimately, we suggest that inviting learners to examine their own literate activities occasions opportunities for them to recognize and value the diversity of communicative resources that have shaped their disciplinary histories. Perhaps more importantly, learners' responses to such invitations make their semiotic repertoires and trajectories of becoming more readily visible for teachers, making it easier to a) recognize that disciplinary writing and knowing emerge from activities that trace across the multiple semiotic modalities and myriad histories of people's lives and b) resist models that would deny those critical pathways of disciplinary writing, doing, and becoming.

References

Abramson, Dor, & Lindgren, Robb. (2014). Embodiment and embodied design. In Robert Keith Sawyer (Ed.), *The Cambridge handbook of the learning sciences.* (pp. 358-376). Cambridge University Press.

Allan, Elizabeth. (2013). Multimodal rhetorics in the disciplines: Available means of persuasion in an undergraduate architecture studio. *Across the Disciplines, 10*(2). http://wac.colostate.edu/atd/articles/allan2013.cfm

Ansell, Katherine. (2020). *Cultivating adaptive expertise in the introductory physics laboratory* [Dissertation]. University of Illinois Urbana-Champaign. http://hdl.handle.net/2142/107872

Anson, Chris. (2016). The Pop Warner chronicles: A case study in contextual adaptation and the transfer of writing ability. *College Composition and Communication*, *67*(4), 518–549. https://www.jstor.org/stable/44783545

Brandt, Deborah. (2001). *Literacy in American lives*. Cambridge.

Durst, Sarah. (2019). Disciplinarity and literate activity in civil and environmental engineering: A lifeworld perspective. *Written Communication, 36*(4), 471-502. https://doi.org/10.1177/0741088319864897

Gallagher, John R., Turnipseed, Nicole, Yoritomo, John Y., Elliott, Celia M., Cooper, S. Lance, Popovics, John S., Prior, Paul, & Zilles, Julie L. (2020). A collaborative longitudinal design for supporting writing pedagogies of STEM faculty. *Technical Communication Quarterly*, *29*(4), 411–426. https://doi.org/10.1080/10572252.2020.1713405.

Gere, Anne, Knutson, Anna V., & McCarty, Ryan. (2018). Rewriting disciplines: STEM students' longitudinal approaches to writing in (and across) the disciplines. *Across the Disciplines, 15*(3), 63-75. https://doi.org/10.37514/ATD-J.2018.15.3.12

Guerra, Juan. (2008). Cultivating transcultural citizenship: A writing across communities model. *Language Arts,* 85(4), 296-304.

Guhlincozzi, Aída, & Cisneros, Julia. (2022). A framework for addressing the lack of diversity in the geosciences through evaluating the current structure of institutional efforts. GeoJournal, 87(Supplement Issue 2), S171-S183. https://doi.org/10.1007/s10708-021-10418-1

Hendrickson, Brian. (2016). Studying and supporting writing in student organizations as a high-impact practice. [Special issue on WAC and high-impact practices.] *Across the Disciplines*, *3*(4), 1-14. https://doi.org/10.37514/ATD-J.2016.13.4.20

Iedema, Rick. (2001). Resemiotization. *Semiotica*, *137*(1/4), 23–39. https://doi.org/10.1515/semi.2001.106

Kells, Michelle Hall. (2007). Writing across communities: Deliberation and the discursive possibilities for WAC. *Reflections, 6*(1), 87-108.

Moriarty, Mary. (2007). Inclusive pedagogy: Teaching methodologies to reach diverse learners in science instruction. *Equity and Excellence in Education, 40*(3), 252-265. https://doi.org/10.1080/10665680701434353

Moss, Beverly. (2002). *A community text arises: A literate text and a literacy tradition in African-American churches.* Hampton Press.

Moss, Beverly. (1994). Creating a community: Literacy events in African-American churches. In Beverly Moss (Ed.), *Literacy across communities.* (pp. 147-177). Hampton Press.

Ochs, Elinor, Jacoby, Sally, & Gonzalez, Patrick. (1994). Interpretive journeys: How scientists talk and travel through graphic space. *Configurations*, *2(1)*, 151-171. https://doi.org/10.1353/con.1994.0003

Prior, Paul. (1998). *Writing/disciplinarity: A sociohistoric account of literate activity in the academy.* Erlbaum.

Prior, Paul. (2010). Remaking IO: Semiotic remediation in the design process. In Paul Prior, & Julie A. Hengst (Eds.), *Exploring semiotic remediation as discourse practice.* (pp. 206–234). Palgrave Macmillan.

Prior, Paul. (2015). Writing, literate activity, semiotic remediation: A sociocultural approach. In Georgeta Cislaru (Ed.), *Writing(s) at the crossroads: The process/product interface.* (pp. 183–202). John Benjamins.

Prior, Paul. (2018). How do moments add up to lives? Trajectories of semiotic becoming vs. tales of school learning in four modes. In Rick Wysocki, & Mary P. Sheridan (Eds.), *Making Future Matters*. Computers and Composition Digital Press. http://ccdigitalpress.org/book/makingfuturematters/prior-intro.html.

Prior, Paul, & Shipka, Jody. (2003). Chronotopic lamination: Tracing the contours of literate activity. In Charles Bazerman, & DavidR. Russell (Eds.), *Writing selves/writing societies: Research from activity perspectives.* (pp. 180–238). The WAC Clearinghouse.

Prior, Paul, & Thorne, Steve L. (2014). Research paradigms: Product, process, and social activity. In Eva-Maria Jakobs, & Daniel Perrin (Eds.) *Handbook of writing and text production.* (pp. 31-54). Mourton de Gruyter.

Reid, Gwendolynne, Snead, Robin, Pettiway, Keon, & Simoneaux, Brent. (2016). Multimodal communication in the university: Surveying faculty across the disciplines. *Across the Disciplines*, *13*(1), 1-29. https://doi.org/10.37514/ATD-J.2016.13.1.02

Remie, Dan. (2019). "Written in the stars": Advocating for an astronomical literacy." *Stylus: A Journal of First-Year Writing, 9*(2), 19-29. https://writingandrhetoric.cah.ucf.edu/wp-content/uploads/sites/17/2019/10/stylus_9_2_Remie.pdf

Roozen, Kevin. (2020). Coming to act with tables: Tracing the laminated trajectories of an engineer-in-the-making**.** *Learning, Culture, and Social Interaction* [Special Issue on Writing Across: Tracing Transliteracies as Becoming over Time, Space, and Settings.], *24*, 1-12. https://doi.org/10.1016/j.lcsi.2019.02.009

Roth, Wolff-Michael. (2003). *Toward an anthropology of graphing: Semiotic and activity-theoretic approaches.* Kluwer.

Roth, Wolff-Michael, & Jornet, Alfredo. (2013). Toward a theory of *experience. Science Education*, *98*(1), 106–126. https://doi.org/10.1002/sce.21085

Stokols, Daniel. (2006). Toward a science of transdisciplinary action research. *American Journal of Community Psychology*, *38*(1–2), 79–93. https://doi.org/10.1007/s10464-006-9060-5

Tsui, Lisa. (2007). Effective strategies to increase diversity in STEM fields: A review of the research literature. *The Journal of Negro Education*, *76*(4), 555-581. https://www.jstor.org/stable/40037228

Ware, Ryan, Turnipseed, Nicole, Gallagher, John R., Elliott, Celia M., Popovics, John S., Prior, Paul, & Zilles, Julie L. (2019). *Writing across engineering: A collaborative approach to support STEM faculty's integration of writing instruction in their classes*. Tampa, FL: 2019 ASEE Annual Conference and Exposition. https://peer.asee.org/33671

Notes

[2] Student names are pseudonyms.

Contact Information

Bruce Kovanen
PhD Candidate
University of Illinois Urbana-Champaign
Email: kovanen2@illinois.edu

Nicole Turnipseed
Teaching Assistant Professor
University of Denver
Email: nicole.turnipseed@du.edu

Megan Mericle
PhD Candidate
University of Illinois Urbana-Champaign
Email: mericle2@illinois.edu

Kevin Roozen
Professor
University of Central Florida
Email: kevin.roozen@ucf.edu

Complete APA Citation

Kovanen, Bruce, Turnipseed, Nicole, Mericle, Megan, & Roozen, Kevin. (2022, November 4). Tracing Literate Activity across Physics and Chemistry. WAC/WID integration in STEM. [Special issue on *STEM and WAC/WID: Co-Navigating Our Shifting Currents*] *Across the Disciplines*, 19(1/2), 62-77. https://doi.org/10.37514/ATD-J.2022.19.1-2.05