An exploratory study of how college students make sense of cancer in writing-to-learn activities in cell biology

Meena M. Balgopal[1, *]
Paul J. Laybourn[2]
Alison M. Wallace[3]
Ellen Brisch[3]

[1] School of Education
[2]Department of Biochemistry & Molecular Biology
Colorado State University
Fort Collins, CO 80523

[3] Biosciences Department
1104 7th Ave S
Moorhead, MN 56563

[*]Corresponding author Email: Meena.Balgopal@colostate.edu

Paper presented at the annual conference of the National Association of Researchers in Science Teaching, Chicago, April 2015

ABSTRACT

Undergraduate biology students are under pressure to learn an overwhelming amount of content presented in foundational courses. We found in previous studies that writing-to-learn (WTL) tasks in small laboratory sections helped students improve quality of arguments and content knowledge. In this study we studied the transportability of WTL interventions to larger (over 75 students) cell biology courses. Students were randomly assigned to either a control group or one of two writing intervention groups, which included weekly WTL tasks for 15 weeks. We collected three essays from each student in the two intervention conditions and conducted content analysis of all essays and rhetorical analyses on a random selection of 10 students (30 essays). Students in both intervention conditions used significantly more abstract cell biology concepts in their final essay compared to their first essay. The rhetorical analyses revealed that the randomly selected students developed different lines of argumentation. Six students began their essays devoted to *definition* lines of rhetoric and then moved into *proposal* or *evaluative* arguments. Four students changed their claims within each iterative writing assignment, while six clarified and strengthened their claims over the writing assignments. All students drew on scientific evidence to support claims from journal readings, class lectures, and textbook in that order even though they were prompted to make personal connections. We conclude that WTL activities in a college lecture course are valuable.

INTRODUCTION

The American Association for the Advancement of Science and the National Science Foundation organized an initiative called, "Visions and Change," in an effort to improve undergraduate life science education (www.visionandchange.org). One challenge that has been identified is helping students make meaning of the overwhelming amount of content often presented in foundational life science courses. In cell biology, for example, students struggle to understand the role of random events and dynamic equilibria in cellular processes (Klymkowsky & Garvin-Doxas, 2008). Howitt, Anderson, Hamilton, and Wright (2008) reported that students erroneously believe that equilibrium is a static state rather than one that is in constant flux; they posit that such beliefs likely arise because cellular processes are not phenomena that can be directly observed. Furthermore, Snow (2010) argued learning is less likely to occur if content is taught as lists of facts than when students have the chance to use them in speaking or writing tasks. Hence, to learn cell biology concepts, students need opportunities to make sense of cellular anatomy (subcellular parts) as well as cellular physiology (processes and forces driving these processes).

Our previous studies with undergraduate biology students demonstrated that conceptual understanding and abilities to construct evidence-based arguments when making decisions about socio-scientific issues (SSIs) improved after the implementation of writing-to-learn (WTL) activities. Our interventions do not center on writing-to-communicate goals; rather, our intentions are to study how iterative writing helps students organize their understanding of science concepts. We found that 64% of elementary education students enrolled in an introductory biology course improved their levels of scientific literacy after completing WTL tasks in small laboratory sections (Balgopal & Wallace, 2009). These students received much in-class guidance. They were taught and encouraged to use concept maps to organize their thoughts, inquiry laboratory activities aligned with the writing topics, the instructor provided time in class for peer and whole class discussion, and the instructor explicitly discussed the scientific concepts central to the SSI that inspired the writing prompt. When we repeated the same study design and analyzed the essays of elementary education majors and biology majors in their respective laboratory sections and did not provide much in-class guidance; we only provided the writing assignment prompts and reading material. We found that only 29% and 25%, respectively, of the elementary education and biology students improved their literacy levels (Balgopal, Wallace, & Dahlberg, 2012). One of our study conclusions was that writing was still helpful to students as they made meaning of scientific concepts but that instructor guidance is still needed to help maximize the impact that writing can have as students organize their thoughts.

In our current study, we examined how similar WTL tasks could be transferred to a large lecture course context in which there are fewer opportunities for discussion. Therefore, our WTL activities were designed to help students make sense of enormous amounts of information to which they are exposed through lectures, textbook reading, supplementary readings, recitations, informal knowledge, and outside sources (e.g., other courses, media, free reading, and jobs). We designed our study recognizing that instructor guidance is still valuable, but we were interested in exploring how best to provide guidance.

THEORETICAL FRAMEWORK

Writing can be a powerful instructional and assessment strategy for helping students both formulate and revise ideas. Writing requires planning and organization; it can be an iterative process that allows learners to "see what they know" and modify their ideas as they construct subsequent drafts (Bereiter & Scardamalia, 1987). Writing reinforces science literacy because it requires students to demonstrate their knowledge of terms and concepts and allows them to construct evidence-supported arguments (Wellington & Osborne, 2001). Often reading assignments precede writing tasks during which students reconstruct their understanding of concepts based on published ideas of others (Flower, Stein, Ackerman, Kantz, & McCormick, 1990). Because scientists often disseminate research findings, criticisms, or conceptual frameworks through writing (Myers, 1990), it seems reasonable to integrate it in biology courses. Unfortunately, many science instructors often fail to do so because they feel that it should be reserved for English composition courses, can be replaced with traditional multiple-choice exams that assess knowledge and recall, or believe that assignments requiring constructive feedback are too difficult and time-consuming (Palmquist, Kiefer, & Salahub, 1998).

This study is grounded in the theoretical framework proposed by Wallace (2004) to study scientific literacy and scientific language use. Wallace describes three constructs of her framework: *Third Space*, *Authenticity*, and *Multiple Discourses*. The Third Space continuum is essential for learners to interpret common understanding, and through negotiated understanding of concepts between listener/reader and speaker/writer messages can be meaningful. Authenticity is important for students to express themselves and move from vernacular to scientific discourse. However, Wallace (2004) explained that this movement only occurs when learners have a reason or a context in which to express themselves and their ideas differently. Finally, Multiple Discourse acknowledges that all individuals engage in different types of communication depending on the context, the content, and our levels of confidence and familiarity with the topic of discussion. Learners move from self-talk (private) to authoritative (public) discourse and adopt different voices in their writing/speaking that reflects their levels of literacy. The latter two constructs informed this particular study because we were interested in the words and context in which undergraduate students expressed their conceptions about cell biology as it relates to cancer. As students write authentically to a friend, we analyzed how they "spoke" about cancer biology and the words they used to convince their friend of an appropriate treatment.

There are many ways to examine written arguments. Many science education studies have examined students' abilities to construct strong evidence-based arguments (e.g., Erduran, Simon, & Osborne, 2002; Osborne, Erduran, & Simon, 2004). Sandoval and Millwood (2010) analyzed students' use of evidence in written arguments and found that students did not always use enough evidence or failed to develop the warrants behind their evidence-based claims. Kelly and Takao (2000) studied how college students moved from grounded claims to theoretical ones and proposed a model of epistemic hierarchy based on evidence and claims in students' arguments. In previous work, we found that students who used blended sources of evidence were more likely to construct stronger arguments based on the Toulmin model, as well as demonstrate higher content understanding relative to their classmates (Balgopal, Wallace, & Dahlberg, unpublished data).

Evidence is meaningful when it supports a claim, and because not all claims are equally relevant to a prompt, evidence presented may seem superfluous or disconnected to the argument being established. Evaluating arguments can be guided by considering Aristotelian topoi (lines of argument). Topoi fall into four main categories: a) *definition* (arguing what something is, also called *exemplary*), b) *evaluation* (arguing the quality of something), c) *proposal* (arguing a solution to a problem); and d) *cause and effect* (arguing about the relationship and causality of events, which some may call *scientific*) (Prelli, 1989). This last topos necessitates that the scientist establishes his or her ethos with the audience by using the norms of the discourse community, including the types of appeals typically used by peers. Interestingly, although these topoi are not meant to represent a continuum, the first two topoi may still be possible for a writer to develop even if he or she uses private voice and vernacular expression (Wallace, 2004), but the latter two topoi require that a writer has a strong enough grounding in conceptual understanding and requiring that they use public voice and scientific expression. Argumentation and reasoning are intimately intertwined, but both are dependent on the types of claims being made, an important point because, as Walton (1990) explained, writers sometimes use "aimless reasoning."

Because the rhetorical qualities of arguments are dependent on content that writers use to support their propositions, we used both content analyses and rhetorical analyses on our data set. This exploratory study began with the broad question, "How do students in large undergraduate courses that have WTL components write about cell biology concepts?" which we asked in two intervention courses.

METHODS

Context

The study was conducted at a Midwestern, land-grant research university. There are two introductory cell biology courses offered on campus for resident instruction: a freshman-level course for biology majors as well as other life science majors and a sophomore-level course originally designed for biochemistry majors, but now taken by a broad range of pre-health life science majors. This study took place in the sophomore-level course. Students attend three hours of lecture a week; however, the instructor of the course is committed to introducing active learning strategies in his course. He records his lectures so students have access to content electronically, he uses clickers as formative assessment, and he regularly employs short interruptions to allow for think-pair-shares during class time. The instructor is a full professor in the Biochemistry and Molecular Biology department who has been active for the past two decades in supporting research opportunities for undergraduates and leading efforts within his college for instructional innovations in the life sciences.

Participants

In this study we recruited students in two lecture sections over two semesters. One lecture section was randomly divided into two sections offered concurrently; and of these, one served as the control section (n ~120), who are not described in this paper, and the second (n = 72) served as our intervention for condition A. The second semester, the course was again divided and students (n = 162) were invited to participate in our study of intervention condition B. Condition A involved WTL tasks each week and generated 15 samples of students work, whereas Condition B involved only WTL tasks three times during the semester, every five weeks.

Across all of the three sections two-thirds of the students were women, and one-third male, and were sophomores, juniors and seniors. Of the 72 students (in condition A), 54 students submitted complete writing sets (all 15 assignments). From this pool we randomly selected 20% of the essays for our exploratory analysis. This generated 10 students: 3 men and 7 women. Of the 10 students, 6 received the grade of A, 2 received a B, 1 received a C, and 1 received a D. Students were graded on their writing tasks, and collectively these grades added up to 16% of the total course grade.

Intervention

Scientifically literate individuals make sense of science through the use of evidence-based reasoning (Brown, Nagashima, Fu, Timms, & Wilson, 2010;) and problem solving of socio-scientific issues—SSIs (Zeidler & Sadler, 2005; Feinstein, Allen, & Jenkins, 2013). When studying SSIs, students may use informal and moral reasoning in their arguments as they draw on their personal knowledge (Sadler & Zeidler 2005; Sadler, 2004). This is important because studies suggest that when learners find science relevant to their lives they are more willing to learn about scientific concepts and practices (Duschl, Schweingruber, & Shouse, 2007; Bransford, Brown, & Cocking, 2000), enabling them to increase their scientific literacy skills (Krajcik & Sutherland, 2010). Hence, as Wallace (2004) argued, scientifically literate individuals can "appropriate academic scientific language into their own forms of communication (p. 95)."

The SSI that student participants in this study read and wrote about was cancer treatment. Although there is no right or wrong cancer treatment, it is necessary to have an understanding of cancer biology before making a decision about what treatment one may want to choose for themselves or recommend to a friend or loved one. Students explored various cancer treatments through readings in journal articles (selected from the *New York Times* and *Science News*), textbook chapters, and through class lectures. Although the large class size was not conducive to regular class discussions, the instructor allowed time for students to pose questions so he could answer them. During the 15-week semester, students had weekly writing tasks that were broken into three large assignments. Two to three journal articles were selected for each of the three assignments, all of which centered on cancer treatment strategies relevant to the content being discussed in class at the same time. Students were prompted to write about how they would advise a friend to treat a diagnosis of cancer. Students were not told what line of argumentation or types of evidence to use in their papers.

Condition A. Students in condition A were provided much guidance during the intervention activities. Students were asked, in order, to choose (we supplied examples) or construct a diagram to organize their thoughts on what they 1) knew (what concepts they had learned from readings and class); 2) felt (how they connected to/reacted to the prompt); and 3) would do (how they would resolve tensions evoked by the prompt). 4) Then, the following week students were randomly assigned to a group of eight (new group for each of the three assignments) and were asked to read/evaluate at least two peers' essays. They were asked to briefly describe the areas of strengths and those needing improvement in their peer's essays and share these on an online writing platform (used by our university's English composition classes) that only other group members and instructors could see. 5) Finally, using the feedback they received on their own graphic organizers, students submitted a self-evaluated essay in which they highlighted their "big ideas/claims," bolded their "reactions," and underlined tensions that they wanted to resolve. An example of the writing prompts for the first writing assignment is presented in Appendix A.

Condition B. Students in another section of the course did not receive much guidance. These students submitted the final three papers at weeks five, ten, and 15. They did not submit collections of thought or participate in peer review. However, they were expected to self-evaluate their essays, as described in condition A.

Data collection

Students in both conditions A and B were asked to submit all written assignments. Students in condition A (guided) submitted three collections of thought, peer evaluation given to classmates, peer evaluation received from classmates, explanation of how feedback informed their final paper, and their final written paper with self-evaluative marks for each of the three writing assignments. Students in condition B (unguided) only submitted the three final essays with self-evaluative marks.

Data analysis

We conducted both content and rhetorical analyses on students' final essays for each of the three assignments, which are described below.

Content analysis. We used a directed content analysis approach and used Wallace's (2004) framework to determine what terms would help us analyze expression and voice (Hsieh & Shannon, 2005). We randomly selected 10 students from condition A who had complete data sets and then analyzed their essays (30 in total) to initially determine what words would constitute the sub-constructs (*parts*, *processes*, and *forces*) that we identified from the literature on cell biology misconceptions (Carney, 1972; Klymkowsky & Garvin-Doxas, 2008; Howitt et al., 2008). These three themes were explicitly used by the instructor all throughout the course and were even used to frame the syllabus and sequencing of topics. However, we also drew on manifest content analysis by recognizing that some terms appeared in the written discourse and informed how we answered our research question (Potter & Levine-Donnerstein, 1999). For example, we did not originally intend to code "cancer terms," but because these terms contextualized the use of the other categories: parts, processes, and forces, it made sense to code these as well. After peer debriefing over several meetings, we used NVIVO to conduct the content analyses on the three essays all of the students submitted in both intervention groups (conditions A and B).

Table 1. Examples of words that were categorized in the original three sub-constructs and in the added sub-construct identified during the manifest content coding (complete code book in Appendix B)

Sub-construct ("big ideas")	**Example**
Parts	cell membrane, mitochondria, Golgi apparatus, DNA, glucose, kinase, oxygen, P-glycoprotein, insulin, ligand, enzyme
Processes	glycolysis, fermentation, respiration, citric acid cycle, metabolism, phosphorylation, expression, apoptosis
Forces	energy, concentration gradient, hydrophobic, non-covalent interactions, caloric energy
Cancer	oncology, treatment, radiation, chemotherapy, tumor, suppressed, melanoma, PET scan

Rhetorical analyses. Essays written by the randomly selected ten students in condition A were analyzed for types of arguments developed. These analyses involved identifying all of the claims students made in each of their essays, which ranged between 330 to 1210 words each. The two most prominent claims (those with the most supporting evidence) regarding decisions on treating cancer were selected for review. These were classified as *definition*, *evaluation*, *proposal*, or *scientific* (Prelli, 1989). The types of evidence (scientific, personal) were recorded.

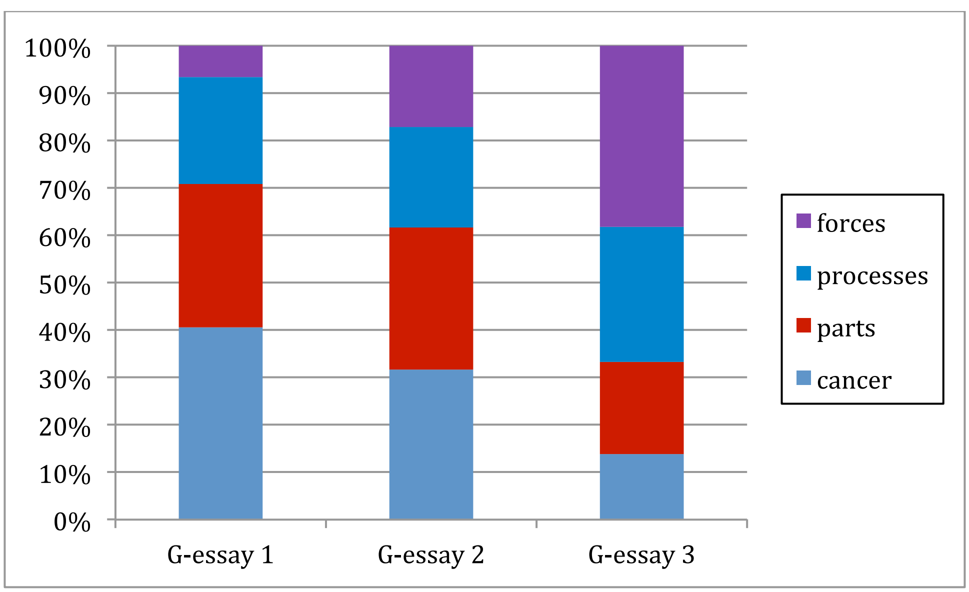
Trustworthiness. Our team was attentive to trustworthiness issues, and we met and discussed the essays over several meetings. With each review of the essays, we clarified our objectives and strategies for coding. We divided the content and rhetorical analyses tasks between two of the authors and a graduate research assistant (who has two degrees in the life sciences and is a doctoral student in the life sciences). Our team of three reviewed each other's findings after we coded three student sets (nine essays) to clarify our analyses and achieved over 90% inter-rater agreement. An external inter-rater coder (a biologist not associated with the class or study) also reviewed three randomly selected essays after being trained using the four topoi codes to ensure trustworthiness of the rhetorical analyses, and a close to 90% inter-rater agreement was achieved. In addition, the process of rhetorical analyses was presented to two experts in the English department who study science discourse, who reviewed and accepted the findings.

FINDINGS

Content analysis

Of the content that was included in essays, *parts* (e.g., oncogene) were mentioned most often and *forces* (e.g., energy production or diffusion) the least often (Figure 1). A chi square test of independence was performed to compare words use between essays in week 5, after participating in guided writing, and 15, the end of the semester. Essays in week 15 used significantly more processes and forces terms than essays in week 5 (X^2, 3, N = 9845) = 956.63, $p < .0001$.

Condition A.



Condition B.

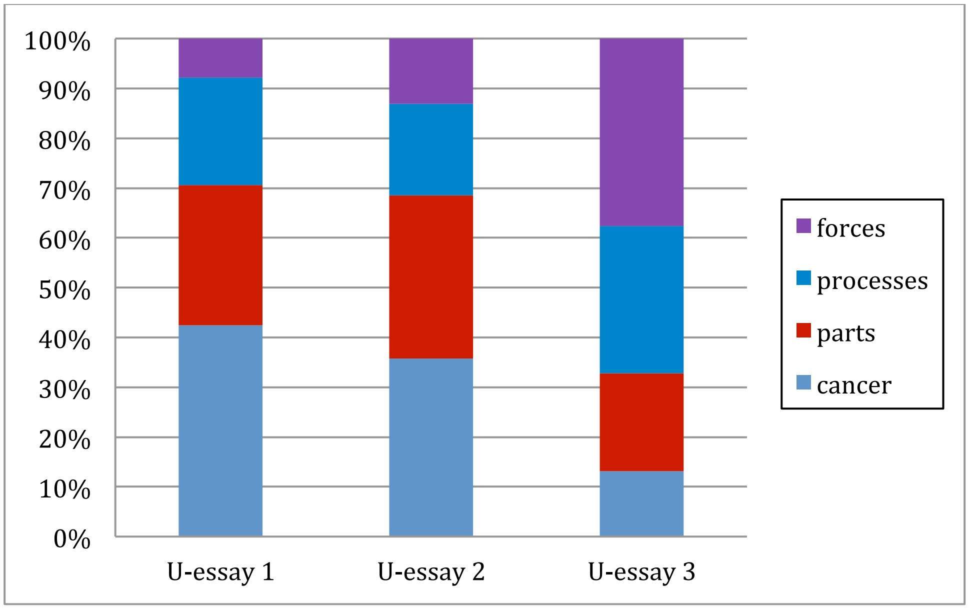


Figure 1. Distribution of codes used by students in the two conditions: a. guided (G-essays) and b. unguided (U-essays).

Rhetorical analysis

The types of arguments that students developed shared rhetorical characteristics even though they varied. Seven of the ten students wrote arguments that could be classified as *definitions*, *evaluation*, and *proposals*. Six students began their essays with a paragraph or two devoted to definition lines of rhetoric and then moved into proposal or evaluative essays. Four students completely changed their claims within each iterative writing assignment, while six clarified and strengthened their claims over the writing assignments. Rhetoric that centered on definition topoi generally presented explanations of how anti-cancer drugs work ("Estrogen receptor antogonists (such as tamoxifen) are drugs that block estrogen production and can be used to prevent or delay breast cancer…"). Rhetoric that centered on evaluation topoi generally considered whether they believed the evidence available supported certain claims of effective treatment ("Radiolabeled fluoro-2-deoxyglucose, while a viable option, has significant limitations such as toxicity at high levels"). Rhetoric that centered on proposal topoi presented claims about how they might approach cancer treatment ("Medicinal plants are a better option to overcome drug resistance than with high doses of chemotherapy drugs").

We asked students to explicitly make personal connections, and half of the essays integrated personal evidence (e.g., "my grandfather died of throat cancer") and as a result, drew on emotional appeals in their essays. None of the essays in the exploratory rhetorical analysis presented scientific topoi. That is, none of the writers developed arguments around causality and correlation. All students, though, drew on scientific evidence to support claims from journal readings, class lectures, and textbook in that order.

DISCUSSION / IMPLICATONS

We were encouraged that all of the randomly selected students in our exploratory study demonstrated increased use of content, and especially abstract content, over the semester. Inviting students to draw on multiple sources of data allowed students to revise their claims accordingly. We are encouraged that participants in both conditions (guided and unguided) showed increased use of abstract content; however, what is necessary now is for us to evaluate how these terms were used and whether they appropriately support scientific arguments. Secondly, we are intrigued by the subtle differences between the two conditions. The fact that the guided writing cohort used more abstract concepts by the final essay compared to the unguided warrants further investigation and begs the question, which we have asked before, how much guidance is needed to maximize student learning outcomes in a time-efficient manner for instructors (Balgopal et al., 2012).

Students' lines of argumentation (topoi) were appropriate for the prompt and although some arguments were more robust than others, all of the students drew primarily on scientific evidence. In addition, students were able to interpret and draw from journal readings to support their claims about a socio-scientific issue (choosing a cancer treatment plan). Because students were reading syntheses of scientific studies, they may not have had enough evidence or felt that it was expected of them to develop scientific topoi to argue. On the other hand, without interviewing students directly, we can never know why or why not none of them chose to center their argument on the last topoi that Prelli (1989) asserts is essential to scientific discourse. In any event, our findings support our claims that WTL tasks are important in not only smaller classes in which there is more instructor-pupil dialogue, but in large college biology lectures.

Using Wallace's (2004) framework, we were able to examine how students moved along the expression continuum by moving from vernacular to scientific language use. Our findings support that, as students explore and learn more terminology and vocabulary, they are able to integrate this language into their written discourse. What was less clear, though, was interpreting students' voice as they moved from private (self-talk) to public (authoritative) discourse. The lines of argumentation that students constructed may be telling of how committed students are to lines of reasoning (Wallace, 2004). We believe that these analyses are valuable, but we recognize that a more thorough analysis of all of the participants is necessary before making definitive conclusions.

We also believe that there are opportunities for science education researchers to examine how students make sense of science as they are developing their ideas during WTL tasks. Prelli (1989) argued that "rhetoric of science" must center, not on the science, but on the logic of scientific thinking behind scientific arguments; scientists ask if arguments are "rhetorically reasonable." In fact, scientists evaluate each other's claims within situated contexts, demanding different expectations of argumentation (Myers, 1990). Scientific rhetoric often follows four major rhetorical topoi, each requiring discursive strategies to convince audiences of its reasonableness. However, for students entering college science classes without training in the culture of scientific discourse, logic, and reasoning it can be overwhelming to make meaning of how science knowledge is generated and interpreted. Regardless of training in rhetoric, though, we believe students make sense of arguments through close readings and opportunities to practice constructing their own arguments for peers (versus expository reports for instructors).

Prelli (1989) explained that scientific discourse is often "written in an inductive style that implies that claims were found through impartial investigation of phenomena that have independent, objective, and undeniable existence. Findings are 'reported' more than argued for. The cumulative effect of such rhetorical strategies is assertion or implication that what is said and done is all that could be said or done within the research situation (p. 103)." Further, scientific writing can be and is often authoritative (Snow, 2010; Wallace, 2004), but if instructors develop prompts that allow students to expose their tentative commitment to a claim, it gives students freedom to build their arguments, exactly like scientists do as they make sense of their own data (Myers, 1990). The question arises, then, how do undergraduates read and evaluate the claims of journal authors as they construct their own papers? Moreover, how do they evaluate their peers' arguments in light of their own growing understanding of concepts (and of communicating their arguments)? Finally, as the science education research community implores science educators to use the claims-evidence-reasoning (National Research Council, 2012) heuristic, it is even more imperative that we do not adhere to a simplified definition of reasoning. There are many types of reasoning that scientists use to construct arguments around different stances or topoi. If educators intend to acculturate developing scientists into the discourse community of scientists, it behooves them to examine the lines of reasoning that are used across scientific discourse. These are all relevant questions about learning that we urge the NARST community to explore.

LITERATURE CITED

Balgopal, M.M. & Wallace, A.M. (2009). Dilemmas and decisions: The use of guided writing to increase ecological literacy of elementary education majors. *Journal of Environmental Education, 40*(3), 13-26.

Balgopal, M.M., Wallace, A.M., & Dahlberg, S. (2012). Writing to learn ecology: A study of three populations of college students. *Environmental Educational Research, 18*(1), 67-90.

Bereiter, C. & M. Scardamalia. (1987). *Psychology of written composition*. Hillsdale, NY: Lawrence Erlbaum Associates.

Bransford, J.D., Brown, A.L., & Cocking, R.R. (2000). *How People Learn*. Washington, D.C.: The National Academies Press.

Brown, N.J.S., Nagashima, S.O, Fu, A., Timms, M., & Wilson, M. (2010). A framework for analyzing scientific reasoning in assessments. *Educational Assessment, 15,* 142-174.

Carney, T.F. (1972). *Content analysis: A technique for systematic inference from communications*. Winnipeg, Canada: University of Manitoba Press.

Duschl, R.A., Schweingruber, H.A., & Shouse, A.W. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, D.C.: National Academies Press.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education, 88*, 915-933.

Evagorou, M. & Dillon, J. (2011). Argumentation in the teaching of science In D. Corrigan, J. Dillon, & R. Gunstone (Eds). *The Professional knowledge base of science teaching (pp.189-203)*. Dordrecht: Springer Publisher.

Feinstein, N.W., Allen, S., & Jenkins, E. (2013). Outside the pipeline: Reimagining science education for nonscientists. *Science, 340* (6130), 314-317.

Flower, L., Stein, V., Ackerman, J., Kantz, M.J., & McCormick, K. (1990). *Reading-to- write: Exploring a cognitive and social process*. New York: Oxford University Press.

Howitt, S., Anderson, T. M., Hamilton, S. and Wright, T. (2008). A concept inventory for molecular life aciences: How will it help your teaching practice? *Australian Biochemistry 39*, 14-17.

Hsieh, H-F. & Shannon, S.E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research, 15,* 1277-1288.

Klymkowsky, M. W. & Garvin-Doxas, K. (2008) Recognizing student misconceptions through ed's tool and the biological concept inventory. *PLoS Biology, 6*, 14-17.

Krajcik, J.S. & Sutherland, L.M. (2010). Supporting students in developing literacy in science. *Science*, *328* (5977), 456 - 459.

Myers, G. (1990). *Writing biology: Texts in the social construction of scientific knowledge*. Madison, WI: University of Wisconsin Press.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching, 41*(10), 994-1020.

Palmquist, M, Kiefer, K, and Salahub, J. (2009). Sustaining (and growing) a pedagogical writing environment: An activity theory analysis. In D.N DeVoss, H.A. McKee, and R. Selfe (Eds.), *Technological Ecologies & Sustainability*. Logan, Utah: Computers and Composition Digital Press.

Potter, W.J. & Levine-Donnerstein, D. (1999). Rethinking validity and reliability in content analysis. *Journal of Applied Communication Research, 27,* 258-284.

Prelli, L.J. (1989). *A rhetoric of science: Inventing scientific discourse*. Columbia: University of

South Carolina Press.

Roberts, C.W. (Ed.) (1997). *Text Analysis for the Social Sciences: Methods for Drawing Statistical Inferences from Texts and Transcripts*. Mahwah, NJ: Lawrence Erlbaum Associates.

Sadler, T.D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching, 41*(5), 513-536.

Sadler, T.D., & Zeidler, D.L. (2005). Patterns of informal reasoning in the context of socioscientific decision making. *Journal of Research in Science Teaching, 42*(1), 112-138.

Sandoval, W.A. & Millwood, K. A. (2005). The quality of students' use of evidence in written scientific explanations. *Cognition and Instruction, 23*(1), 23-55.

Snow, C.E. (2010). Academic language and the challenge of reading for learning about science. *Science, 328*, 450-452.

Walton, D. N. (1990). What is reasoning? What is an argument? *The Journal of Philosophy, 87*(8), 399-419.

Wellington, J. & Osborne, J. (2001). *Language and literacy in science education*. Buckingham, U.K

Zeidler, D.L., & Schafer, L.E. (1984). Identifying mediating factors of moral reasoning in science education. *Journal of Research in Science Teaching, 21*, 1-15.

Appendix A. Writing Prompts

Using the assigned reading assignments and any other information you have gathered from class reading, discussions, other courses, your own experience, etc. respond to the following prompts.

Prompt 1: Imagine that a friend or relative of yours was diagnosed with cancer and was considering treatment with anti-cancer drugs. Think about how you might explain to them what you know about anti-cancer drugs and how they work.

Prompt 2: Consider your personal connections and reactions to what you know about anticancer drugs and their role in the treatment plan for this person.

Prompt 3: What actions might you take as you consider this imaginary situation of your friend or relative going through cancer treatment?

ESSAY ASSIGNMENT: Use this information to construct a short essay (~1-2 pages) about the decisions you will make (i.e. what will you do) regarding anti-cancer drug treatment.