ARTICLE
The Use of Haiku to Convey Complex Concepts in Neuroscience

Alexia E. Pollack[1] **& Donna L. Korol**[2]
[1]Biology Department, University of Massachusetts-Boston, Boston, MA 02125; [2]Biology Department, Syracuse University, Syracuse, NY 13244.

Conveying scientific content with accuracy and fluency takes practice and requires deep understanding of the concepts being conveyed. This depth of knowledge comes from internalizing information and constructing it into a form that is unique and coherent to the individual. Often in science classrooms there is little or no opportunity for students to practice this type of thinking, activities that we believe are fundamental to effective science communication. This article describes the use of haiku – a 17 syllable poem – as a means for students to convey neurobiological concepts in a succinct manner by forcing them to focus on the most salient features of the observed processes. In our assignments haiku writing was successfully paired with explanations of the students' thought processes (Addiction course) or the scientific evidence to support claims (Neurodegenerative Disease course). We provide examples of student haiku and explanations as evidence of the power of this approach. The coupling of poetry and prose together create rich, accurate descriptions of scientific phenomena by encouraging higher-order thinking. Poetry writing can thus be used across the curriculum to forge comprehension of complex ideas in any discipline and to bridge the arts and the sciences.

Key words: poetry; science haiku; written communication; scientific literacy; deconstructing science; non-traditional STEM writing; innovative assignments; writing to learn

Scientific inquiry is extolled for its objective observational and experimental approaches that rely upon critical linear thinking, logical analyses, and astute problem solving skills. However, there is growing acceptance, and hints from classical and contemporary figures, that more subjective features like creativity, imagination, and intuition play important roles in determining the impact of scientific discoveries (Gurnon et al., 2013). Interestingly, scientists with prestigious stature, such as Nobel Prize Laureates, are more likely to have an artistic avocation compared to the general public or other scientists (e.g., Sigma Xi members), and are more inclined to be artistic than even honored scientists who are Royal Society and National Academy of Sciences members (Root-Bernstein et al., 2008). Santiago Ramón y Cajal, the Spanish neuroscientist who won the 1906 Nobel Prize in Physiology or Medicine for anatomical findings showing that neurons were individual cells, was himself a passionate visual artist and fiction writer (Ramón y Cajal, 1901-1917). Thus, the observation that scientists highly recognized for innovation are also artists supports the idea that the insight and creativity needed to generate scientific paradigm shifts may correspond to artistic creativity.

The connection between honored scientists and engagement in artistic endeavors also suggests that the creative process in and of itself may enhance the conceptual understanding of science. For example, students at DePauw University participated in an innovative cross-curricular Chemistry–Art collaboration where they created a series of large-scaled stainless steel sculptures to represent the process of folding in the prototypic protein, villin (Gurnon et al., 2013). Students used general principles of protein biochemistry as well as molecular details about villin to conceptualize the sculptures and to plan their construction. Interestingly, the process of building these sculptures sparked probing scientific questions about protein structure and function that align with contemporary theories of protein biochemistry currently under investigation (Gurnon et al., 2013). As such, the hands-on creative process experienced by these students seemed to stimulate significant insight and scientific inquiry. Moreover, that the students were engaged in real-world activities throughout the project, including designing, welding, and displaying the protein art, may have brought the chemistry course content to life. Indeed, relating scientific content to real-world scenarios can facilitate student understanding and memory for that information (Waldvogel, 2006), an important outcome for both student and teacher.

In addition to testing for content knowledge, written assignments can improve learning of scientific concepts by asking students to apply their knowledge. There are countless types of assignments that can be construed to tap specific types of information processing and varying depths of thinking from lower to higher orders according to Bloom's revised taxonomy (Krathwohl, 2002). For example, assignments can ask students to articulate ideas based on empirical observations in the laboratory (written abstracts or laboratory reports) or their reading (textbook, primary empirical papers, scientific reviews), which oftentimes require remembering, understanding, applying, analyzing, and evaluating. Less often, however, do assignments encourage, or even allow for, high levels of creativity, artistic imagination, or open-ended responses. Moreover, long laboratory reports and research papers are often high-stakes assignments making their execution and completion more daunting than composing shorter pieces of writing. There is evidence that limiting the length of

writing assignments to very short, 'microtheme' assignments, in which students have limited space to hone their ideas without emphasis on grammar or mechanics, is an effective practice in the classroom (Leahy, 1994; Collins, 2004a; McMillian, 2013). On top of this, writing can be particularly anxiety provoking for students in STEM fields (Alberts, 2010). Therefore, by incorporating short forms of written expression, students who would otherwise be anxious about writing have an opportunity to practice and improve. Indeed, work with English Language Learners emphasizes the importance of writing as a means to learn, often by using a variety of low-stakes or non-graded assignments (Zamel, 2000). In this way students can think through or deconstruct new and often complicated ideas themselves. As an added benefit, when students are asked to write about their reading, they become ready to engage with the material in the classroom, with ideas 'rehearsed' beforehand in writing.

Taking these ideas and approaches to heart, we have developed assignments that use the writing of haiku – a 17 syllable poem - as a means for students to identify key neurobiological concepts and to articulate them in an extremely succinct yet creative manner. Along with constructing their haiku, students were asked to deconstruct their thought processes (A. Pollack's course) or to offer explanations of their haiku using scientific evidence to support claims (D. Korol's course). As such, these haiku assignments ask students to take scientific explanations of phenomena or models found in textbooks or primary sources of literature and to construct a succinct representation of this information. Haiku's inherent brevity, focus on nature, and deployment of imagery and imagination make it a useful form of poetry for teaching biological concepts (Rillero, 1999; Rillero et al., 1999; Waldvogel, 2006). We believe our haiku assignments reflect novel approaches to science literacy, which has high priority in education reform (Webb, 2010).

In this article we provide examples from our assignments and students' work that we feel highlight the power of this approach in helping students think creatively and take ownership of their knowledge.

I. Course on Addiction, University Honors Program, UMass-Boston (14 students)

The assignment

To prepare for the haiku assignment, students read a section in the textbook about addiction models (Meyer and Quenzer, 2005) and had access to PowerPoint slides created about this material. Each student was assigned a model (Negative Reinforcement, Positive Reinforcement, Incentive Sensitization, Opponent Process, Susceptibility, Exposure, and Biopsychosocial), and asked to write a haiku that captured something specific about the model – i.e., what the model deemed important about explaining addiction. Below the haiku, students also had to write a paragraph explaining how they created their haiku, which reflected their understanding of the model. All addiction models in the textbook were assigned, and each model had several students writing about it. The assignment was graded, but its credit represented only 2% of the course grade. The day the assignment was due, instead of lecturing, students presented their haiku. At the end of class, students received index cards and were asked to write their thoughts (anonymously) about (1) doing the written assignment and (2) presenting their haiku in class in lieu of hearing a lecture about the same material.

Excerpts from students' writing

Negative Reinforcement Model of Addiction – as interpreted by two students.

(1)
I know I must stop
Withdrawal holds me captive
My drug is my cure

(2)
No more Mary Jane
Weird dreams and all tense; I know
I need to get more

Both haiku captured key elements of the negative reinforcement model: that the symptoms of withdrawal ("weird dreams and all tense") drive addictive behavior ("withdrawal holds me captive"), and thereby serve to lead the addict back to their drug of choice in order to relieve the withdrawal symptoms ("my drug is my cure''; "I need to get more").

In addition, the author of haiku #1 describes how she created her haiku, which provides insight into her thought processes and expands on her understanding of this model:

"….I wanted to address the cycle presented of the addict attempting to stop drug use, facing withdrawal symptoms and then relapsing. It seems the key factor in this model is the pain of withdrawal, which is likely too unbearable for the addict to abstain from drug use for long. I thought it would be interesting to imagine the addict's mindset in relation to this model, which is why I chose to write in first person. I would imagine that the addict knows the drug is ultimately killing him/her, hence the first line 'I know I must stop'. The figures in the book and lecture slides also acknowledge this by saying there are attempts of abstinence. Abstinence, however, is difficult when dealing with the highly unpleasant symptoms of not having the drug anymore. I thought this withdrawal pain would be tortuous for the addict to the extent that he/she feels imprisoned or caged, which is why I said in the second line 'Withdrawal holds me captive'. The immediacy of his/her pain would override their decision to stop the drug use, and at the moment the only thing that can alleviate that pain is the drug of choice, hence the last line 'My drug is my cure.' It is as if the addict is in a holding cell, the withdrawal symptoms are the big scary cellmate, and the drug is the one who comes to pay the bail, ultimately freeing them.

Ironically the drug that is hurting them becomes the thing that heals them."

Incentive Sensitization Model of Addiction - as interpreted by two students.

(1)
I cannot help it
This drug is so rewarding
My body craves it

(2)
I take it again…
Even though I like it less,
It's still more wanted.

These haiku both capture the essence of the Incentive Sensitization Model with its emphasis on craving/wanting as driving addiction ("This drug is so rewarding…My body craves it"; "It's still more wanted"). Haiku #2 also conveys another important aspect of this model: the dissociation of drug craving, which is enhanced ("It's still more wanted"), from drug liking, which diminishes ("Even though I like it less").

Opponent Process Model of Addiction

First drug take is good
Bliss is gone when addicted
All due to more drug

While the Opponent Process Model is similar to Incentive Sensitization Model in that repeated exposure to drug is thought to change/alter the responsiveness of specific brain regions, this student's haiku adeptly captures this model's essential features. Her explanation creates a more complete picture: "…In this model, a person feels pleasure when they are taking the drug at first. However, once they become addicted they no longer are able to experience the same pleasure.....Drug-induced euphoria is diminished in addicted individuals. This causes them to no longer feel the same pleasure that they once experienced each time they repeatedly take the same drug. Therefore, abstinence is difficult to maintain because pleasure set-point remains low. This haiku shows how first a person feels very good when they start the drug; however, the repeated drug use causes them to feel worse just because they can't get the same response. I wanted this short haiku to capture how the person first feels when they start the drug and how they feel after they keep taking more of the same drug."

Exposure Model of Addiction

Tried it a few times
My brain kept telling me more
I lost all control

On its own, this haiku sounds like a generic explanation of addiction, but coupled with the student's description of its construction, the specificity of this model emerges: "…In the exposure model, it is hypothesized that an alteration in a drug abuser's brain is to blame for their addiction. After repeated use of a drug of abuse, significant alterations in the abuser's brain cause them to 'lose control.' The exposure model argues that addiction is fundamentally a brain disease due to changes in brain structure and function that occur. In the beginning, when the person chooses to initially try the drug, it is a voluntary behavior; however there is a point where that voluntary behavior becomes involuntary. As a result of prolonged drug abuse, a metaphorical switch in the brain is flipped, and an addiction is born."

Biopsychosocial Model of Addiction

Susceptible genes
effected by surroundings.
Multifaceted.

On its own, this haiku is less specifically about addiction. There is no mention of drug, behavior, or the brain; its interpretation is quite open-ended. However, its word choice and telegraphic-style aptly capture this model's most salient features – especially when coupled with the student's explanation: "The biopsychosocial model of drug addiction is an attempt to encapsulate the complexity of substance abuse in each individual. What previous models lack is the multifaceted surface of the biopsychosocial model. It involves (as its name suggests) biological, psychological, and sociological factors. What this model emphasizes, and what I found most important is the importance of an individual's environment in determining behavior. This ranges from family upbringing and parenting (or lack of), influence of friends and peers, and the general environment in relation to drug availability, crime, education, and other protective factors from drugs. Along with this 'multifaceted' model of addiction is the biological component, which emphasized that an individual's genes make him/her more susceptible to certain temperaments and traits. This model emphasizes that differences in individuals range from such environmental factors discussed above and genes in determining beliefs, personality, and behavior in initial and repeated drug use. I chose to emphasize this relationship through the emphasis of genes that are effected by its surroundings in this multifaceted model."

What was learned from the haiku assignment

Students' haiku coupled with their explanations showed a deep understanding of these addiction models. Their approaches were creative, often metaphorical, and their explanations shifted between common and scientific language as a means to gain fluency with each style. The struggle to convey these addiction models within the narrow structure of haiku was evident, and student comments on index cards described this struggle in some depth: (1) "I thought trying to cram a whole model into a haiku was tough – there was only 17 syllables to work with!

But it did help isolate the important aspects of these models, which I found useful." (2) "Doing the haiku assignment forced me to focus on the importance of my addiction model because I had to make sense of it in 17 syllables only. In a way less work was more work because although the assignment was basically a sentence long, I had to make it count." Indeed, their haiku showed precision in word choice, and since students were required explain these choices, this, in turn, reinforced language precision. Their comments also spoke to intellectual challenge of this assignment, which was more complex than simply asking for a summary. Instead, students had to *construct* haiku based on their reading/understanding, then, *deconstruct* the haiku in order to explain how they represented their addiction models. To do this, students were forced to focus on the most important features of their models, and this aided the learning and retention of this information – an assertion supported by students' index card comments: (1) "Doing the assignment was really helpful. I was having a hard time remembering the specifics of each model and being able to sum it in a few words really helped it stick. It was also fun." (2) "It really helped me to understand the particular model because I was ultimately explaining what I knew about the model in a brief non-complicated way." (3) "Doing the assignment made me think deeper and get a better understanding of my addiction model."

The haiku assignment carried into the classroom

On the day the haiku assignment was due, instead of lecturing, the students wrote their haiku on the blackboards in the classroom, organized by addiction model. Students took turns reading their haiku out loud and sharing how they were constructed. The haiku helped draw forth the models' most salient features, which was aided by having more than one haiku representing each model (compare two haiku for Negative Reinforcement and Incentive Sensitization Models, respectively). Surrounded by haiku written on blackboards, students were able to point to similarities and differences between addiction models. This student-centered approach was possible because everyone came to class prepared (written haiku and explanation), with equivalent material to present (haiku were same length/format). Student index card comments were uniformly positive of this teaching approach – praising: (1) the chance to hear from classmates ("At first I was skeptical of what I could learn from a bunch of haikus, but it worked out well and definitely was easier to remember than a standard lecture because I got to hear different voices give their own explanations."), (2) the way this approach elaborated on each model ("I think the class period perhaps helped to draw out more of the details behind the models, and it was cool seeing everyone else's creativity in the haikus."; "I also liked how we ran class instead of a regular lecture because we (students) got to talk about the material and cover any missing aspects. It was easier to remember the material afterwards."), (3) the opportunity to demonstrate their own understanding ("The class went well. To some degree I felt like I was teaching the model and that showed me that I learned.").

II. Syracuse University, Undergraduate / Graduate Biology Seminar (22 students)

The assignment

In a mixed undergraduate / graduate seminar course on Neurodegenerative Diseases, students created haiku focused on any one of eight diseases we discussed throughout the semester. The objective was to imagine the disease from molecular to molar, and then to identify a salient feature that students would capture in poetry. Students wrote two-page explications using course material to support the imagery generated by the haiku construction; these were submitted along with the poems. The haiku were not graded, but the accompanying explications were. Worth only 4% of the total points for the course, the assignment was relatively low-stakes but still required students to use evidenced-based argumentation and reasoning (McNeill and Krajcik, 2008a; 2008b; Krajcik and Sutherland, 2010) to validate their poems. Students were given a grading rubric for the explication so they were aware their work would be marked for accuracy of claims, use of evidence to support claims, clarity in reasoning, and writing mechanics. With the permission of each student, poems were anonymously collated into a booklet and handed out on the last day of class scheduled for the course wrap-up. Students were allotted several minutes to read through the booklet before starting the final discussion of broad course themes and topics. They seemed proud to have their work showcased and liked reading the poems of classmates.

The haiku was one of six written homework assignments developed to tap a variety of different intellectual processes that benefit the evolving scientist. In addition to more standard writing of research summaries or synopses, other non-traditional, yet inquiry-based assignments asked students to generate questions based on reading of scientific text or to use course material to evaluate the accuracy in print and internet news pieces, television shows, feature films, and advertisements. While these other assignments prompt both lateral and linear thinking, require connection to popular media, and incorporate evidence-based practices, writing of haiku was the assignment that explicitly required students to distill complex concepts into simple forms in a creative fashion. From the following examples, it is apparent that students were able to deconstruct the essence of key concepts related to neurodegenerative diseases that, at times, were quite complicated, and to reconstruct them into concise, powerful examples, which were then prone to the cycle of deconstruction and reconstruction for the longer explication. Interestingly, by chance their haiku fell into one of three categories, aligning broadly with the overarching topical organization for each disease we discussed in class: 1) Disease characteristics, 2) Challenges to Dogma, and 3) Synthesis and Application (see examples below). Commentary about the poems was based upon explications generated by the students in combination with the primary literature cited therein.

Excerpts of students' writing

1) Characterizing the Diseases

These five haiku artfully capture different aspects of four diseases we discussed in class: Huntington's disease (HD), Alzheimer's disease (AD), Parkinson's disease (PD), and Lafora's disease.

Huntington's disease

Rhythmless dancer
Singing lyrical outbursts
A born performance

This student incorporated her ideas about the chorea (literally meaning dance) and tics that many HD patients must painfully endure. The "Rhythmless dancer" metaphor is used to support this student's idea that the movement disorders associated with HD interfere with the normal rhythms of life that healthy patients experience. The third line alludes to the genetic underpinnings of the disease and points to class discussions on the ethics of diagnostic testing in unborn children.

Alzheimer's disease

Waking up one day
Walks to the kitchen, confused
Madam, who are you?

Alzheimer's patients forget
Beta-amyloid builds up
Life without a past

These two poems each highlight the prominent memory loss that characterizes AD but from different perspectives. The first one highlights the daily issues suffered by AD patients and their loved ones, who, as emphasized in the last line, may no longer be recognized by their once-loving spouses. The second AD poem accurately identifies that amyloid, but not necessarily plaques, builds up to create cellular dysfunction that leads to memory loss. The last line of the poem also alludes to the likelihood that for the AD victim who survives long enough, eventually most, if not all, remote episodic memories will be lost, forcing the AD victim to "live in the present" a quality discussed in class.

Parkinson's disease

Dopamine goes bad,
Receptors stop working right,
Motions freeze, time stops.

This haiku focuses on the connection between the neurochemical loss of dopamine and the shift in neurotransmitter receptor sensitivities that might accompany PD and its treatments. The change in the cadence in the third line effectively personifies the severity of problems PD patients face in initiating volitional movements at later stages of the disease.

Lafora's disease

Lafora bodies
Glycogen degradation?
No autophagy.

This haiku about Lafora's disease stood out because it incorporated very current theories for the molecular and cellular dysfunctions that lead to the disease.

2) Challenging Dogma

The following haiku demonstrates that students could distill and succinctly express key points raised in class discussions that broke down the old dogmas about the molecular theories of AD.

Beta amyloid,
Plaques and tangles of tau too
Mark, not are the cause.

The author of this poem conveyed quite clearly the gold-standard positive markers of AD, plaques and tangles, and their respective protein constituents, β–amyloid and tau. The challenge to the dogma comes in the third line of the poem when the student presents one prominent contemporary idea that these inclusions are likely markers and not causes of the disease.

3) Synthesis Across Topics and Application

Letters in a line
Defining who and what, but
Are they really me?

This haiku evaluates the validity of examining diseases using genetic approaches. It subtly incorporates the idea that genes code for proteins but do not define the organism. The student symbolizes DNA in the first line with her text "Letters in a line," which also conveys the rigidity or highly organized feature of the genome. The juxtaposition of the question in the last line with the second line opens up debate as to how nature and nurture interact to produce the individual as a whole. These concepts were discussed at length in the course and clearly incorporated into the student's thinking.

Appearance deceives
The losses go by unseen
Yet clear to the eye

For each disease we discussed issues of disease detection including how definitive diagnoses are made using behavioral assessments, genetics, and neuropathology often done post-mortem. The haiku addresses key points for diseases such as PD where early stages can go unnoticed and where the neurodegeneration is only obvious during histological examination but not from external assessment of the brain.

Red wine consumption
Fight ROS and alter pathways
Protective limits?

This haiku connects the scant evidence that consuming resveratrol found in red wine is neurally protective with the findings that resveratrol can be an antioxidant, eliminating reactive oxygen species (ROS). The student then ends with the question to highlight the paradox of neuroprotection by alcohol that itself can produce neurodegeneration.

Outcomes of haiku writing assignment

Students used course concepts, readings, and other resources to construct their haiku and to build compelling arguments to support them. Compared to responses to other homework prompts, students' explanations of their haiku were by far the most scientifically accurate and well-articulated. When asked to reflect on the process, students remarked that the constraints of the 17 syllables made them consider word choice and concept more intensely than any other writing assignment in the course. Some students commented that it was the most creative yet focused writing they had completed in college. Because the haiku writing was the final assignment, there was insufficient class time to dedicate in-depth discussion to the poems. However, students remarked that reading the booklet of haiku from classmates with different perspectives stimulated new thoughts about topics already discussed, and, in turn, perhaps made them more likely to participate in the whole-class discussion.

Having students use haiku to explain complicated concepts in biology can easily be adapted to large classes. For example, the approach taken in the Addiction class could be formed into a jigsaw exercise for a large class. Students would first break into small groups to share poems and discuss course content and then regroup as a class to discuss key concepts from those discussions. Alternatively, using haiku as a written assignment alone (Collins, 2004a) may be an effective tool in a larger class to foster the development of evidence-based reasoning. The haiku construction and evidence-based explanation described here has been implemented in classes of up to 150 students with apparent success. In the Neurodegenerative Diseases seminar, and in other larger courses on Hormones and Behavior, and Neurobiology of Aging, students often commented that haiku writing on topics ranging from synaptic plasticity to menopause was one of the most memorable exercises they completed in a science course.

DISCUSSION

As captured in students' written responses and recollections, the haiku writing process and explanations created a context for deconstructing complex concepts into simple terms and then reconstructing them to produce descriptions that reflected deep meaning. The haiku assignments fostered logical thinking skills, guiding students to understand that claims need to be supported by evidence that is, in turn, synthesized by the student's reasoning. This framework has been shown to be effective in high school science classes (McNeill and Krajcik, 2008a; 2008b) even when laboratory or hands-on exercises are not enacted. In a college seminar class, an active discussion can become a 'thought laboratory' where students use informal and formal paradigms (see van der Sanden and Meijman, 2004) to make observations, claims, provide evidence, and reasoning through critique of the existing literature. The approaches used in our classes were inquiry-based according to current views of teacher practices and student requirements to process claims, evidence supporting the claims, reasoning, and possibly even revisions to claims, e.g., in the Addiction class (McNeill and Krajcik, 2008a).

We also believe that asking students to provide a 'brief summary' of their addiction or neurodegenerative disease models would not have produced work as rich and thoughtful as that created by the pairing of haiku with explanation. Composing the haiku plus the evidence-based reasoning together required a series of active deconstructions and reconstructions that seemed to engage lateral thinking or synthesis within and between topics. This process encouraged students to think in creative and novel ways about their models and to recapitulate the science in their own terms, similar to the learning cycle of explorations followed by concept development and application (Collins, 2004b). In fact, unlike the haiku and their explications, responses to other writing prompts (Syracuse University course) often included paraphrased texts from primary scientific literature or course PowerPoint presentations that were not particularly creative or unique to each student. However, since we did not use a formal assessment comparing conventional teaching methods/assignments to our haiku assignment, we cannot be certain that our approach significantly affected student learning outcomes.

Our goals for incorporating haiku writing in our respective classes targeted both intellectual and pragmatic outcomes. Aligned with our other assignments, a major objective was to deepen understanding of course content, neuroscience principles, scientific practice, and importantly, to improve scientific communication skills. Indeed like most forms of poetry, haiku is frugal with words, requiring concise language and precise word choices. Students often have difficulty distilling complex concepts into simple or even singular terms, even after hearing or reading examples. Interestingly, when undergraduate researchers were asked to use a single sentence to describe their current project, none of ten students queried was able to generate a broad yet informative summary that would be easily conveyed to a general high-school educated audience (D. Korol, unpublished observations). In contrast, writing haiku may help oral and written communication skills by using common language that is highly descriptive, rich in imagery, and accessible to the reader or listener, thereby fostering the ability to generate concise, scientifically accurate texts. Cognitive gains to readers and listeners of haiku may also be afforded by

forcing them to fill in the holes between words, to connect the dots, and thus conjure deeper meaning from the text. Therefore, having students share their haiku, either orally as in the Addiction course or in writing as in the Seminar on Neurodegenerative Diseases, aids in their classmates' understanding of the material as well.

The use of metaphor, imagination, and creativity to synthesize course concepts aligns well with Bloom's highest level of processing (Krathwohl, 2002) and may facilitate scientific thinking (Gurnon et al., 2013). The creative and flexible nature of our haiku assignments can engage students with diverse backgrounds and talents. It also allows students to connect the course content to their lives and apply it to real world settings making the information more salient (Waldvogel, 2006). Findings from semantic encoding experiments suggest that a simple association between a list of individual words and meaningful contexts significantly increases retention of those words compared to words studied for structural features such as numbers of syllables or letters (Craik and Tulving, 1975; Brown and Mitchell, 1994). Moreover, these haiku assignments were likely to tap cognitive processes that were different from other written assignments, allowing students with different learning or processing styles to excel. Teaching neurobiology so students become critical thinkers and effective communicators is complicated by the varying degrees of content knowledge, comfort and skill with writing, and complexity of concepts that is a part of the typical college classroom. Therefore, diversifying written assignments may increase the likelihood of success in a diverse classroom.

The process of science requires deconstruction of the natural world in order to measure or quantify the object or process under study. These quantifications then need to be rebuilt into meaningful and readily accessible constructs in order to convey findings and theories to others. Depending upon the context, the reconstruction of the natural world (data, theories) can take many forms, from graphs (basic reconstruction) to narratives found in review papers, research reports, grant applications, press sound bites, classroom explanations, etc. As scientists, we are asked to communicate complex scientific concepts in diverse contexts, each with its own language. Therefore, writing haiku may be an effective means for students to practice scientific fluency by forcing them to write with clarity and conciseness. This should, in turn, serve to enhance the very communication skills needed for conveying science to different audiences.

REFERENCES

Alberts B (2010) Prioritizing science education. Science, 328:463.

Brown AS, Mitchell DB (1994) A reevaluation of semantic versus nonsemantic processing in implicit memory. Mem Cognit, 22:533-541.

Collins MAJ (2004a) Using short pieces of writing (microthemes) to improve student learning. In: Teaching tips: innovations in undergraduate science instruction (Druger M, Seibert ED, Crow LW, eds) pp 7-8. Arlington, VA: National Science Teacher Association Press.

Collins MAJ (2004b) The Learning Cycle, In: Teaching tips: innovations in undergraduate science instruction (Druger M, Seibert ED, Crow LW, eds) pp 5-6. Arlington, VA: National Science Teacher Association Press.

Craik FIM, Tulving E (1975) Depth of processing and the retention of words in episodic memory. J Exp Psychol Gen 104:268-294.

Gurnon D, Voss-Andreae J, Stanley J. (2013) Integrating art and science in undergraduate education. PLoS Biol 11: p. e1001491.

Krajcik JS Sutherland LM (2010) Supporting students in developing literacy in science. Science 328:456-459.

Krathwohl DR (2002). Revision of Bloom's taxonomy: an overview. Theory Pract 41:212-218.

Leahy R (1994) Microthemes: An experiment with very short writings. College Teaching 42:15-18.

McMillan SL (2013) Bravo for brevity: Using short paper assignments in international relations classes. International Studies Perspectives Doi: 10.1111/insp.12003.

McNeill KL, Krajcik J (2008a) Inquiry and scientific explanations: helping students use evidence and reasoning. In: Science as inquiry in the secondary setting (Luft J, Bell R, Gess-Newsome J, eds), pp 121-134. Arlington, VA: National Science Teachers Association Press.

McNeill KL, Krajcik J (2008b) Scientific explanations: characterizing and evaluating the effects of teachers' instructional practices on student learning. J Res Sci Teach 45:53-78.

Meyer JS, Quenzer LF (2005) Psychopharmacology: drugs, the brain and behavior. Sunderland, MA: Sinauer Associates.

Ramon y Cajal S (1901-1917) Recuerdos de mi vida [Translated and edited by EH Craigie and J Cano (1996) Recollections of my Life, 3rd ed., MIT Press, Cambridge, MA].

Rillero P, Cleland JV, Conzelman KA (1999) The nature of haiku. Science and Children 37:16-20.

Rillero P (1999) Haiku and science—observing, reflecting, and writing about nature. J Coll Sci Teach 28:345-347.

Root-Bernstein R, Allen L, Beach L, Bhadula R, Fast J, Hosey C, Kremkow B, Lapp J, Lonc K, Pawelec K, Podufaly A, Russ C, Tennant L, Vrtis E, Weinlander S (2008) Arts foster scientific success: Avocations of Nobel, National Academy, Royal Society, and Sigma Xi members. J Psychol Sci Tech 1:51-63.

van der Sanden MCA, Meijman FJ (2004) Evidence-based science communication: An essay. Sci Commun 25:272-287.

Waldvogel JA (2006) Mating Darwin with Dickinson: how writing creative poetry in biology helps students think critically and build personal connections to course content. In: Handbook of college science teaching (Mintzes JJ and Leonard WH, eds), pp 185-194. Arlington, VA: National Science Teacher Association Press.

Webb P (2010) Science education and literacy: imperatives for the developed and developing world. Science 328:448-450.

Zamel V (2000) Engaging students in writing-to-learn: promoting language and literacy across the curriculum. Journal of Basic Writing 19:3-21.

Received July 13, 2013; revised August 12, 2013; accepted August 21, 2013.

This work was supported by the Biology Department (UMB) and NIH SEPA R25 RR024251. The authors would like to thank the UMB Honors Program and the poets in Honors259 (UMB) and Bio400/600-M005 (SU).

Address correspondence to: Dr. Alexia E. Pollack, Biology Department, University of Massachusetts-Boston, 100 Morrissey Blvd, Boston, MA 02125 Email: alexia.pollack@umb.edu