

WRITING AND READING MULTIPLICITY IN THE UNI-VERSE: ENGAGEMENTS WITH MATHEMATICS THROUGH POETRY

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Several years ago, while preparing to teach a graduate holistic education course, Nenad stumbled upon a poem “A Love Letter”, by Nanao Sakaki (1996):

Within a circle of one meter
You sit, pray, and sing.
Within a shelter ten meters large
You sleep well, rains sounds like a lullaby.
Within a field a hundred meters large
Grow rice and raise goats.
Within a valley a thousand meters large
Gather firewood, water, wild vegetables, and Amanitas.
Within a forest ten kilometers large
Play with raccoons, hawks, poison snakes, and butterflies.
Mountainous country Shinano
A hundred kilometers large
Where someone lives leisurely, they say.
Within a circle ten thousand kilometers large
Walking somewhere on the earth.
Within a circle one hundred thousand kilometers large
Swimming in the sea of shooting stars.
Within a circle a million kilometers large
Upon the spaced-out yellow mustard blossoms
The moon in the east, the sun in the west.
Within a circle ten billion kilometers large
Pop far out of the solar system mandala.
Within a circle ten thousand lights years large
The Galaxy full blooming in summer.
Within a circle one billion light years large
Andromeda is melting away into snowing cherry flowers.
Now within a circle ten billion light years large
All thoughts of time, space are burnt away.
There again you sit, pray, and sing.
You sit, pray, and sing.

After reading the poem and reflecting on its structure, Nenad wrote his poetic response, “My Universe”:

Within a circle of one meter
I sit alone, listening to classical music
Within a circle ten meters large
I am in my garden picking tomatoes: tear drop
and indigo rose.

Within a circle a hundred meters large
I say hello to my neighbour.
Within a circle a thousand meters large
I walk from my house to the farmer’s market.
Within a circle ten kilometers large
I visit my friends and their daughter.
Within a circle 100 kilometers large
I escape the hustle and bustle of a big city.
Within a circle 10,000 kilometers large
I hope there are no more wars and nobody is hungry.
Within a circle 100 thousand kilometers large
I am waving goodbye to the satellites.
Within a circle 100 million kilometers large
I see Venus dance around the Sun.
Within a circle ten billion kilometers large
I wave goodbye to our planetary family.
Within a circle 10 light years large
I greet Barnard’s star.
Within a circle 100 light years large
I see more stars.
Within a circle 1000 light years large
I see the dance of the seven sisters, and many more.
Within a circle 10,000 light years large
It’s a mosaic of stars, clusters, and nebulae.
Within a circle 100,000 light years large
I grasp the whole Milky Way.
Now within a circle a million light years large
I embrace galaxies and the whole universe.

At the same time, Susan was teaching an elementary mathematics teaching methods course at a small US Mid-western liberal arts college and was looking for ways to engage her anxious teacher education students with mathematics. Nenad suggested poetry as a safe way into mathematics and together we read “A Love Letter”, discussing our reading of the poem, our interpretation and identification of mathematical themes and structures. We both recognized the structure of the poem’s concentric circles and representations of scale within the stanzas, from the initial increase by a factor of ten (*i.e.*, 1 m, 10 m, 100 m, etc.) to the jump to 10,000 km and following a similar geometric increase to the leap to light years. We also identified the geo-

metric content of the poem, the position of the concentric circles of the stanzas, and that our visualization very often assumed that all objects are coplanar.

Along with mathematical themes and imagery, we appreciated the very personal nature of Sakaki's poem and the threading of his emotions through the verses. We understood the close proximity of basic needs (sleep, shelter, sustenance, and spirituality), the extended connections to Earth and the universe, and the feelings, perhaps Sakaki's and definitely our own, of awe and wonder at the expanse of our world. In this way, we saw the poem to be personally authentic [1]. In our collective sense making of Sakaki's poem, we reflected on the title of the poem, something that both of us glanced over in our initial and individual readings of the poem. We interpreted that the "love" mentioned in the title relates to Sakaki speaking to a person ("you") and that this person is central in his poetic universe: it begins with this person and ending with the circle that encompasses her or him. We also looked at Nenad's poem and the shift of the centre point of his concentric stanzas from "you" and an external individual to "I" and the internal self. For Nenad, the act of writing a responding poem and contrasting it with the original poem extended his poetic analysis.

We also saw the poems as being a part of long tradition of disciplinary interplay encouraged by both mathematicians and poets, by mathematical poets and poetic mathematicians, throughout history (Glaz, 2011). Poetry related to a range of mathematical topics, including counting (e.g., problem solving in *The Cattle Problem* by Archimedes), geometry (e.g., Samuel Taylor Coleridge's *A Mathematical Problem* which celebrates the beauty of a geometric proof), algebra (e.g., 16th century Italian mathematician and engineer Niccolo Tartaglia's *Solving the Cubic*), and calculus (e.g., *Treatise on Infinite Series* by Jacob Bernoulli), has spanned history from ancient civilizations to contemporary cultures and societies. Mathematics can play with and in poetry in many ways and Growney (2009) differentiates between two different types of mathematical poetry. A mathematical process or principle might provide the structure of the poem as in the sonnets that always have fourteen lines of ten syllables each or in experimental poem such as in Kostelanetz's (1981) *From Fibonacci* that contains a graphic arrangement of Fibonacci's numbers. Alternatively, a poem can include mathematical imagery and vocabulary such as circles, parallel lines, and angles that add meaning and depth to the poem.

An invitation to mathematical poetry

After working with Nenad through the readings and analyses of "A Love Letter" and "My Universe," Susan decided to bring poetry into her mathematics teaching methods course. She read "A Love Letter", "My Universe", and three other exemplary poems written by Nenad's graduate students to her students, and for their weekly reflection assignment Susan asked them to write a similar poem about their place and connect it to their exploration of place value done in the previous week. She encouraged them to be creative with their writing, noting to them that they probably were not used to writing poetically and creatively in mathematics. Susan did not give much direction beyond this; students

were free to express content and context as they wished. There was a lot of uncertainty and unease, and some students chose not to do the reflection at all. A total of 10 poems were written and shared the following week in class; several students enthusiastically read their poetry aloud while others were more hesitant and asked Susan to read their poems to the class. Susan then shared the students' poems with Nenad and Limin. All three of us read the poems on our own. Next, we discussed together the poems confirming and collating (and in some cases eliminating) themes and ideas identified in our individual readings.

Embracing multiplicity

Our initial reading and discussion of the students' mathematical poetry was narrowed to focus almost exclusively on the specific mathematics content knowledge that we hoped for our students to share in their writing. We were looking for accurate representations of distance and scale, and we wanted to find students making real connections between mathematical measurements and their lived experiences. We hoped to read poems that took up our invitation to engage with mathematical poetry, and poetic mathematics, and illustrated their understanding and application of mathematical content. And, we were disappointed to find that students' engagement and enthusiasm about mathematics was very different from ours. Our initial perceived lack of mathematics in the poems necessitated their re-reading and our setting aside of the very comfortable lenses of mathematics educators. While mathematics as commonly recognized did not seem to be presented in the students' poems, was mathematics altogether absent? Our opening of teaching mathematics to the inclusion of poetry also required an opening of our thinking about mathematics, of what it was and what it could be.

As our engagement with mathematical poetry was quite different from that of our students, we found it necessary to unpack what it means to read poetry broadly and mathematical poetry in particular. In doing this, we identified that the meanings of 'reading', 'mathematical', and 'poetry' are themselves contested, something that does not necessarily show up in much of the discussion about mathematics and poetry. In doing so, we started questioning whether the text, and for us the poem, stands on its own as an independent object with a finite interpretation that is true for all readers. In other words, we challenged the formalist approach to poetry that assumed that all readers decode textual structures in the same and ideal way thus rendering interpretation a predictable process with a singular outcome (Guerin, Labor, Morgan, Reesman, & Willingham 2005). Scholars of mathematical poetry that follow a formalistic approach examine primarily the structure of the poem including its mathematical themes and how they connect to other ideas. The identity of the author, and the reader, is of little importance in formalist poetic interpretation. The meaning is in the structure, not in the reader.

As educators, we recognized the dismissal of the reader (our students and also ourselves) and finiteness of interpretation as problematic. As we explored more recent approaches that allow for the multiplicity of meanings and interpretations, we traced the theorizing of Jacques Derrida

(e.g., 1978, 1997) and Roland Barthes (1977) in order to think more deeply, and perhaps more poetically, about what it is that we did when we invited students to write mathematical poetry and necessarily consider what it might mean to read and to write mathematically and poetically. According to Derrida, meanings are not stable but are instead caught up in the endless play of relations and difference between signifiers (words) and signifieds (concepts). And this play is dependent on the reader and the reader's prior uses and understandings of and experiences with those signifiers and signifieds.

The dismissal of the reader in classic formal criticism has been problematized by Roland Barthes (1977). He asserted that the reader is not to be ignored in the process of interpretation. Rather, the reader takes on the role of authorship in producing the text in her very reading of it. Before the reader, the text is only signs. A reader is required to bring meaning to those empty signifiers. Barthes proposed that the reading and subsequent interpretation of any text is a *writing of a new text*. The interpretive possibilities are infinite and dependent on the knowledge, experiences, and beliefs of the reader. There are as many texts as there are readers:

A text is made of multiple writings, drawn from many cultures and entering into mutual relations of dialogue, parody, contestation, but there is one place where the multiplicity is focused and that place is the reader, not as was hitherto said, the author. The reader is the space on which all quotations that make up a writing are inscribed without any of them being lost; a text's unity lies not in its origin but in its destination. (Barthes, 1977, p. 148)

According to Derrida and Barthes, textual meaning is seen as constructed in the experience of reading (Guerin *et al.*, 2005). In other words, all texts require the interpretive space of the reader's knowledge, experiences, and beliefs to construct meanings that can be shared in dialogue with others in a community of readers. The meaning of a poem is not a fixed characteristic in the process of its reading but rather it is created by the reader using a repertoire of interpretive strategies including cues and schemata provided by external sources to construct their own textual understandings. For example, when a poem is labeled as 'historical,' or 'spiritual,' or even 'mathematical,' the reader works this genre classification into their interpretative process of decoding poetic themes, meanings, and ideas thus weaving those threads into their meaning making.

For some the notion of multiplicity of meanings or interpretive difference is problematic because it resists an endpoint of reading that is singular. It belies the truth that is seen to reside in the text. However, allowing multiplicity of meanings does not imply the 'free play' of signs. All interpretations are rooted in signs and signifiers that are evoked by objects, experiences, and concepts that exist in the real world. But it is the meaning of the signs that we make that generates difference of interpretation. The ethic of reading is to open up meaning making to a questioning of 'mind-independent truths' that limit freedom of responses and promote silence instead of dialogue (Trifonas & Jagger, 2015).

Re-reading and writing mathematical poetry and poetic mathematics

We recognize that the reading of poetry is influenced by the readers' personal experiences, understandings, and beliefs, and since the interpretation of a text can be viewed as a passing on of 'authorship' in the reader's re-writing of the meaning of the poem, we believe that the subjective space and the blurring of 'author' and 'reader' can make poems more authentic, that is meaningful, relatable, and relevant for students.

Our re-reading and writing of the students' mathematical poetry and poetic mathematics illuminated the centrality of personal authenticity as the poems were highly expressive acts in which students expressed their experiences, emotions, and recollections. Several students described in their poems day-to-day lived experiences and many wrote about their routines at the residential college (e.g., coffee brewing, getting books ready for class, meeting friends in the halls, struggling with early classes, etc.), and at home on the family farm (e.g., roosters crowing, mother cooking fresh bacon and farm eggs, herding cattle in the pasture, harvesting corn and beans, etc.).

Along with presenting everyday experiences, some students' poems were playful in their subject and their textual choices. This allowed students to share with lightness and humor their experiences, something not always prevalent in mathematics assignments. This play can be read in Mabel's poem:

Procrastination Connections

Within a 1 meter circle, my phone vibrates,
tempting me to connect with the outside world.

Within a 10 meter circle, the elevator dings,
reminding me to make a few trips to check the mail
and connect with my peers.

Within a 100 meter circle, the grass blows in the breeze,
connecting me to a friendly pickup game of football.

Within a 1,000 meter circle, the campus lies before me,
connecting me with professors and classmates
as I take a stroll.

Within a 10 kilometer circle, the golden arches of
McDonald's glow, connecting me to my
Dr. Pepper addiction.

Within a 28 kilometer circle, Buffalo Wild Wings
tempts me with their specials, connecting me
to the best food group, chicken wings.

Within a 100 kilometer circle, Peoria unfolds before me,
connecting me with endless restaurants
and procrastination stops.

Mabel highlighted her love of Dr. Pepper and chicken wings, a comical and unexpected insert within her poem that, for the most part, described common events and contexts in her life. Mabel followed Sakaki's template with a growing pattern, but broke from the pattern in the fifth line to specify the exact distance, 28 kilometers, to the purveyor of her beloved chicken wings. Additionally, we see Mabel's

understanding of scale as her measured distance to Buffalo Wild Wings was accurate and her other measurements are similarly mathematically sound.

While some of the students' poems were light and whimsical, others turned more inward and were highly emotive as they shared feelings and experiences very close to their hearts (*e.g.*, grief following loss of family member and friend, anxiety and insecurity about becoming a teacher). These students deepened the personal authenticity of their poetry with the moving presence of affect. For example, Elizabeth's poem traced her experience of loss with the passing of her grandfather:

My Grandpa

Within a circle of one meter
I hold my mother's hand

Within a circle ten meters large
We sit on a pew in church listening to the service

Within a circle a hundred meters large
The funeral procession drives slowly

Within a circle a thousand meters large
We drive to the cemetery only blocks away

Within a circle ten kilometers large
I no longer feel your presence

Within a circle a hundred kilometers large
I realize that my world has changed forever

Within a circle ten thousand kilometers large
A flock of geese flies overhead

Within a circle a hundred thousand kilometers large
I realize that you are watching over me from above

Within a circle a hundred million kilometers large
You are my universe

Within Elizabeth's poem, we could situate her emotions in the specific events of that day and how as the distance in each stanza increases so does the breadth of her reflection. Her poem closed with her understanding that her grandfather would always be with her and that her love for him was endless.

Elizabeth's poem did suggest that her sense of numeracy broke down as her measurements grew. Although mathematically accurate up to her use of 1,000 meters (similar to many of her peers), Elizabeth made, for example, an error at 10,000 kilometers when describing the height at which geese fly. We assert though that her lack of accurate number sense does not mean that she was not engaging with mathematics. We believe that she simultaneously worked mathematically and poetically while she used relative numbers and distances as representative metaphors. Those distances closer to her, the one, ten, 100, and 1000 meter measures, shared the specific actions experienced on the day of the funeral. Reading on, the poem's distance extended to a scale beyond which Elizabeth did not seem to be able to make numerical sense of. The vastness of the distances, the 100, 10,000, 100,000, and 100,000,000 kilometer measures, represent the expanse of her loss and her love for her passed grandfather. It is also worth noting that Elizabeth incorpo-

rated a third dimension in her description ("overhead", "from above") and we feel that this further suggests the breadth and depth of her thinking and feeling. Given Elizabeth's spirituality that can be read in the poem, it can be speculated that she is referring to her belief that he is in heaven. This reminds us of another bringing together of mathematics content with mathematical representation and engagement: Susan Gerofsky's (2011) claim that we historically associate the vertical axis with heaven (positive values) and hell (negative values).

Engaging differently with mathematical poetry and poetic mathematics

The learning experience created by the overlapping space of mathematics and poetry opens up a meaningful and safe place for students to explore mathematics. In a previous exploration of mathematics and poetry in this journal, Triandafillidis (2006) discussed an earlier attempt by Koch, outlined in his 1970 poetry education book, *Wishes, Lies, and Dreams*, to include mathematics in poetry writing and questioned why the children did not write interesting mathematical poems and why their teacher was unable to motivate children's mathematical poetry writing. In our case we acknowledge, following the arguments above, that the students' experiences with words and concepts (signifiers and signifieds in Derrida's sense) are different from ours. For example, the distances at the beginning of each stanza did not evoke the associations of exponential growth as it did for us. We recognize, however, that in some of the poems and with various degrees of accuracy, the students did engage with mathematics. Moreover, there are elements of their authentic engagement with poetry where students use mathematics to connect with their own world. This engagement can be seen as realistic (*e.g.*, distances in Mabel's poem) or metaphoric (*e.g.*, using numbers to describe intensity of feelings in Elizabeth's poem). Through their bodily situation in the world (*e.g.*, Elizabeth holding hands with her mother within a circle of one meter), some students were able to engage with mathematics as an embodied experience. This is quite significant for mathematics, a field of study that is often seen as disembodied and abstract, and confirms Gerofsky's (2011) claim that "the dream of a wholly abstract, idealized, disembodied mathematics is simply not achievable; mathematics is a system of human interpretation of the world and has human qualities inextricably woven into its very nature" (p. 14).

How do we reconcile the multiplicity of meanings with our effort to gain insight into students' mathematical knowledge and engagement? We see poetry's greatest potential as a space for students' exploration of mathematical concepts. In this paper, we only present the students' poems, but a more complete investigation of poetry would include students' reading of poetry (*e.g.*, Nanao Sakaki's poem), collective sharing of the concepts they found in the poems, followed by writing, sharing, and rewriting the poems in order to investigate mathematical concepts and their connection to other themes. Therefore, the idea is not for educators to unidirectionally gain insight into students' knowledge, but for students to develop their own conceptual understanding through the exploration of mathematical concepts in the context of poetry.

In this way, we see mathematics and poetry aligned with Davis and Renert's (2014) view of mathematics as collective, connected, and context dependent enterprise in which the focus is on knowing (something dynamic) rather than knowledge (something static). Thus, through poetic reading, writing, re-reading, and dialogue, students are engaging in the continual and collective process of knowing mathematics.

We might consider those mathematically accurate poems to be poetic mathematics and those that embrace mathematics in their expression to be mathematical poetry. Or, perhaps, this is an unnecessary distinction and we can simply recognize their complementarity and nurture the author's and the reader's mediation with, and in, the spaces of mathematics and poetry, and of poetry and mathematics.

Note

[1] We borrow the term *personal authenticity* from Murphy, Lunn, and Jones (2006). A concept is understood to be personally authentic if it addresses an issue that is important to an individual.

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