CREATIVE WRITING IN MATHEMATICS AND SCIENCE

Florin Diacu
Department of Mathematics and Statistics
University of Victoria
and
Marjorie Senechal
Department of Mathematics and Statistics
Smith College

10–15 November 2013

Overview

Mathematics and science more usualy reach the general public through journalism, popularizations, fiction, biographies, plays, poems, and other forms of literary writing. Our workshop series, Creative Writing in Mathematics and Science, aims to create a critical yet supportive community of writers who share this goal. Like the first four highly successful BIRS workshops of this title, we brought together 21 mathematicians, scientists, and journalists to discuss their work-in-progress. We also expanded cooperation between BIRS and the Banff Center's Writing and Publishing program, to the benefit of both. This is the longest direct collaboration BIRS has established with the Banff Centre for the Arts.

The visible achievements of previous BIRS workshops include, in addition to many publications of individual participants (see the Bibliography for a partial list),

- a well-attended public reading in Max Bell Hall in June 2006,
- playwright Ellen Maddows math-laced music comedy "Delicious Rivers," written in collaboration with Marjorie Senechal, which was performed at La Mama Cafe in New York and at Smith College in 2006,
- the work of 20 past workshop participants showcased in *The Shape of Content*, an anthology of creative writing in mathematics edited by the three co-organizers of the third workshop. This book generated rave reviews, [1],
- the panel discussion "Breaking Barriers: Writers, Scientists, and Mathematicians in Conversation," a joint event of our group and the writers in residence at the Banff Centre, a highlight of the workshop we held in 2010,
- a public reading of our current work at this workshop, which people from the Banff Centre, including some of the writers in residence, attended. This series was videotaped and posted on BIRS's website.

How the workshop was run

Some of our participants identify themselves primarily as writers, others as mathematicians or scientists who also write about their field. Our common goal was to exchange ideas, help improve each other's writing, and find new and ingenious ways to reach the general public through creative writing.

All five workshops in this series, including this one, have been guided by three axioms:

1. Every participant must bring work-in-progress to be critiqued by the group.
2. We – all of us – are the teachers and we – all of us – are students. We have much to teach, and learn from, each other.

3. All genres are welcome. Novelist can learn from poets, journalists from playwrights, biographers from popular-science writers, and so on in all permutations.

The daily organization was simple. On arrival at BIRS, each participant signed up for a one-hour slot for his or her work to be critiqued. (There were three slots each morning, Monday through Thursday, and three each afternoon except Wednesday, which as usual was left free for hiking, touring, or solitary work. On Friday morning we discussed the workshop itself and planned for the future.

On Monday and Tuesday evenings, we gathered after dinner for participant-led discussions of topics of common interest (e.g., writing for interactive media; can fiction convey mathematics?). On Wednesday evening Florin Diacu gave a well-attended public lecture on Megadisasters, the subject of his recent book [3] in the Banff Centre Lecture series, and on Thursday evening we held the public reading of our work mentioned above.

We (the organizers) asked each participant to describe what they had expected from the workshop and what they gained from it. We have organized their responses by literary genre. Within each genre, the contributions are alphabetical.

1 Poetry

Possibly the oldest, most difficult, and finest form of writing, poetry has found inspiration in mathematics and science. Six poet-participants brought their work in progress: Madhur Anand, Robin Chapman, Adam Dickinson, Emily Grosholz, Joanne Growney, and Philip Holmes.

Madhur Anand: I presented several poems from my first book-length poetry manuscript-in-progress. These poems contain scientific ideas and concepts to varying degrees and in differing manifestations. Ecological objects and systems are used for imagery and to describe narratives that transcend traditional scientific boundaries, where humans are objective observers of Nature to socio-ecological systems in which human stories can find metaphor in ecological histories and be informed by them. In several poems I am entwined in the narrative through personal experience. This raised questions about the ways in which science and personal life can become manifest successfully. They also opened up a larger discussion about the role of form in poetic expression, in particular the use of strict (almost-mathematical) forms such as the villanelle, as well as the use of syllabics. Feedback from the group ranged from inspiration from general discussion around my work to specific suggestions for line edits in my poems. All of this will prove useful in my final preparations of my manuscript. I also learned a lot from workshopping other work which will certain affect my writing practice.

Robin Chapman: I brought a working manuscript of poems entitled Six True Things, about my childhood growing up in the scientists' Manhattan Project town of Oak Ridge, Tennessee. I received a wonderful, encouraging, helpful range of feedback. It was an extraordinary experience to have readers conversant with a whole range of scientific, mathematical, and philosophical content who were also knowledgeable about the workings of metaphor, prosody, and narrative and willing to be open to personal experience. Comments from other writers who had grown up in similar circumstances in government towns highlighted for me the safety and freedom of our childhoods, a theme that had been backgrounded in my own thinking; these readers enlarged and validated my project of trusting that early childhood experience is relevant to the growth of the curious scientist and mathematician. Other participants gave me insightful feedback on the emotional trajectory of individual poems, including those poems that needed a turn or insight in their final lines; or helpful editing that tightened the prosodic line of a poem. Still others pointed out the need for breaking the manuscript (and the long table of contents) into sections whose length would be less intimidating to a reader. Sharp-eyed appreciators of form in poetry pointed out extra lines in stanzas; knowledgeable mathematicians pointed out that Lorenz should be Lorentz; novelists pointed out the usefulness of enlarging lists into small narratives. And I learned much about writing–and science and math!–from reading the work of other participants, listening to others' commentary on it, and thinking about the creative opportunities that different projects offered–from art installations of choose-your-own adventure stories to short stories of teaching science in Inuit towns to Puzzle of the Week in math emails to biographies of famous and infamous mathematicians to tender poems

using math metaphors to a play dramatizing Pasteur's solution to the mystery of silkworm deaths. It was a splendid week!

Adam Dickinson: I outlined a research-creation project entitled "Anatomic" that involves biomonitoring and microbiome testing to produce a book of poetry that reframes the body (my body) as a being overwritten by toxic chemicals yet constantly subject (in necessary ways) to the biosemiotic interference of other microbial lifeforms.[1] My objective is to combine innovative trends in contemporary poetics with science and environmental ethics by researching and writing poetry that will emerge (in terms of themes and methodological approaches) from a toxicological and symbiotic map of my own body. By focusing on the outside that is inside, I hope to draw attention to the coextensive and intra-active nature of the body with its environment and the consequent implications for linking the human to the nonhuman and the personal to the global in environmental ethics.

This creative research project makes several significant and unconventional interventions into environmental literature and contemporary poetry. It enacts unusual scrutiny upon the nature-writing self, an area often treated in overly general terms by environmental writers. Furthermore, my focus on the self directs conceptual poetics back into the subjective realms it has often eschewed as part of its critique of voice and personal anecdote in lyric poetics. My project proposes a highly original approach to ecologically informed poetry through the yet largely unexplored possibilities of biosemiotics and pataphysics (an avant-garde art movement that combines science and artistic practice). In an age when questions of biotechnology and anthropogenic environmental degradation have become vexingly pertinent, a project such as this that asks fundamental questions about how we write the environment and how the environment writes us is both timely and necessary.

I received very valuable feedback from my workshop colleagues. I gained important insights into relevant issues associated with genomics, cryptography, the history of sugar, and the immune system. I also learned about highly relevant readings in science fiction, poetry, and bacterial studies that will help me further conceptualize and frame this project. I found the BIRS workshop an unprecedented opportunity to receive unique feedback from exceptional writers, mathematicians, and scientists concerned, as I am, with intersections between science and writing. My previous project for an earlier version of this BIRS workshop (2010) was eventually published as a book, *The Polymers*, [4], which was a finalist for the 2013 Governor Generals Literary Award for Poetry. I credit my BIRS experience with helping me to re-imagine The Polymers in new and ultimately constructive ways.

Emily Grosholz: I brought my essays and poems on the development of number theory to BIRS in the hope that the writers would let me know if my ideas were philosophically interesting, and the mathematicians would tell me if I was getting the details straight and seeing the big picture. Donal OShea, who has written very well on the work of Riemann and Poincar and late nineteenth century mathematics, was a good source of information, and I was glad to learn about his book *The Poincar Conjecture*, [5]. My old friends JoAnne Growney, Joe Mazur and Marjorie Senechal were, as always, full of good ideas and suggestions, and inspired me with their experiments in various genres: poetry, the novel and drama. Clearly the discovery of new theorems or the solution of odd problems involves inspiration, a fascinating plot, and high drama! I was happy to get to know two talented younger colleagues, Gizem Karaali and Madhur Anand, and to find out about the intersection of mathematics and ecological concerns in the work of Robin Chapman, Adam Dickinson, Florin Diacu and Sandy Bonny. What better place to think about the fate of the earth than the Canadian Rockies, where the snow-dusted mountains were present day and night, and the occasional elk came up close to our meeting rooms and looked in the windows? Josy Fox, in her memoirs, gave me rich material to take back to a philosophy and pre-med undergraduate who is writing about issues of autonomy in medical care, and Jacob Goodman provided deep and interesting commentary in many discussions. I think the main thing I came away with, was the sense that mixing genres can be legitimate and indeed a source of insight; so I have just sent off to different small presses a manuscript that combines poems and essays about mathematics and another that combines poems, reviews and articles about science. The energy and exuberance of my fellows

[1] I am testing my blood and urine for over 200 chemicals (such as such as Phthalates, PCBs, OCPs, PFCs, OPIMs, PAHs, BPA, as well as Parabens, Triclosan, PBDEs, and heavy metals). I will also obtain a deep metagenome and virome characterization of a stool sample, plus additional marker gene sequencing (16S rRNA, 18S rRNA and ITS) to characterize not just the bacteria but also the viruses, microbial eukaryotes, and fungi in my stomach.

at this workshop, working in so many different ways at the intersection of mathematics and literature, was an inspiration.

JoAnne Growney: I arrived at Banff with beginnings for a poetry project that conveys to non-mathematicians, particularly to poets, authentic experiences of the nature and poetry of mathematics. My goal for this project is that non-math readers will agree with Bertrand Russell and say The true spirit of delight, the exaltation, the sense of being more than man, which is the touchstone of the highest excellence, is to be found in mathematics as surely as in poetry. One focus for the project considers the properties of prime numbers and one of the poems (More and More Primes) examined by the conference group was a dialogue between a left voice and a right voice. It generated a variety of comment concerning novelty (comparison of a proof-by-contradiction to assumption of guilt of a defendant while trying to prove innocence), historical accuracy (Euclid did not use proof-by-contradiction in his verification of the infinitude of the primes) and voice (the costs and benefits of following or violating male-female and poet-mathematician stereotypes) and so on.

Another of my poems, entitled Love! – it is insisting that we love mathematics – earned praise from readers for its lively voice (a sort of serious light verse) and the readers had varied comments on its word choices. To illustrate, here are stanzas 3 and 4:

> Welcome, as the sculptors do, the Mobius band
> whose one-sidedness does not offend.
> Cherish, within reason, paradoxical points
> of view: mathematics is – by turns – constructed,
>
> partitioned, dreamed. Love it with a love
> that does not tend to 0. Refuse to scorn
> the rationals for their repeating patterns of values.
> Escape the reals to imaginaries and n-tuples.

In the first of the stanzas above, the phrase about the one-sidedness of the Mobius band was praised; the latter stanza was considered much less fresh in its imagery than the former and n-tuples was agreed to be a poor choice of term at the end. Among these specific comments about the work presented were asides that, in retrospect, seem more valuable than the specifics: suggestions of additional topics to include in the project; alerts to printed and online articles and work-samples that might offer models for project development; and, probably most important, encouraging words throughout!

Phil Holmes: I read and discussed several poems, one of which ("Minding one's business") had been presented in early draft at the 2010 workshop. This piece belongs to an evolving cycle of short poems (10-30 lines) that draw on my mathematical work and current research with neuroscientists. Along with the other poems discussed ("Archaeology", "Intermediate values", "Approaching, 6am", and "Gray matter"), "Minding" concerns the relation of models, mathematical and otherwise, to the phenomena that they address, and how they help, or perhaps hinder, our understanding. For example, given the mass of data emerging from new experimental methods, I am interested in the question of how much detail is necessary, or useful, in models of brain function. In general, how should we balance the specific and general in probing our experiences and sharing them with others, in both the arts and the sciences?

2 Fiction

We interpret "fiction" broadly to include novels, short stories, plays, and other prose works of the imagination. The fiction writers at this workshop were Sandy Bonny, Robert Dawson, Jacob Goodman, Patrick Ingram, Gizem Karali, Joe Mazur, Arturo Sangalli, and Marjorie Senechal.

Sandy Marie Bonny: I presented an outline and chapter excerpts from an interdisciplinary narrative-inquiry book project, *A Living Earth–living narratives of Saskatchewan/ kisiskīciwani-sīpiy*, that will be published by TrueHeart academic in the fall of 2015. The project draws together living narrative understandings related to Saskatchewans cultural and physical geography and geology, blending academic and nonacademic voices

in a multivocal text grounded in its place. Intersections of story across Saskatchewans Indigenous, imported, and emergent perspectives highlight ways in which narratives are heard by listening local environments and transmitted to future generations inheriting an era of environmental and cultural change. Discussions within the BIRS workshop contributed perspectives on the narratives that affect dialogue broadly across disciplines and during the public dissemination of math and science. The potential to frame discussion of emergent narratives with reference to adjusting, unevenly weighted initial parameters and boundary conditions was discussed and workshop participants shared examples from math and mathematical modeling to strengthen theorization regarding the importance of counterfactual stories to dialogue between domains. Some of our narrative choices are conscious, many are unconscious and emerge from intrinsic metaphors; the importance of listening to narratives that are very different from our own is essential to identifying our own narrative inconsistencies. A Living Earth is intended for a broad audience and attention at the workshop was accordingly paid to the precision and fluence of prose, and authentic translation of field texts to creative nonfiction.

Robert Dawson: I presented a short story, "Ladies' Night", in which a Las Vegas scammer tries to take advantage of academics' proverbial love of explaining things. A statistics conference is in town; she finds a suitable victim among the conference participants, and asks for an explanation of the famous Monty Hall problem, intending to guide the conversation in her own carefully-chosen way. However, things do not go quite as planned.

The story is written for a nonmathematical readership in a genre crime fiction style. It could find an eventual home in a crime magazine such as "Hitchcock's."

Workshopping the story with this group was a very positive experience. I got several different views on the psychological aspects of the story, which were of considerable help in revising it. Also, I was able to hear from readers with varying backgrounds just which aspects of the Monty Hall problem they felt needed to be discussed in the story, and which aspects went without saying (or could usefully be omitted.) I remain a strong believer in the value of creative writing as a way to expose the interested public to solid scientific concepts. The operative word here is "expose," not "teach." Its probably better, especially with so much information easily available on the Internet, to leave the reader curious, rather than trying to make the story into a self-contained lecture.

The opportunity to see what other writers were doing with ideas from mathematics and other sciences was also valuable. A particularly special part of the week was the reading on Thursday night. A very significant number of those attending the workshop read their work, and many chose material to read that was quite different from the works in progress that had been discussed and analyzed earlier in the week.

I am also working on another short story, provisionally entitled "Diversion Program," that was inspired by Florin Diacu's public talk at Banff. It involves an astronaut taking part in a mission to divert a rogue asteroid, who finds parallels between the mission and his own past life.

Jacob Goodman: I had never written a novel before. For the past two years I'd been working on one about a mathematician – a German refugee in the United States – who disappears suddenly many years after the war, and whose disappearance intrigues a young mathematician who tries to discover its causes. After she learns about his life in Germany and what happened to him there before he managed to get to the States, she hits a dead end and is forced to give up the search. But then a memoir he has penned turns up and explains all. The memoir, which forms the largest part of the book, is both a bildungsroman and an account of a mission to spy on the American scientific establishment before and during World War II. In it, a number of real-life figures – among them Admiral Wilhelm Canaris, Professor Felix Hausdorff, and Professor Emil Artin – play significant roles.

The comments I received from the various participants, both about the novel's plot and about the chapter I presented, were immensely helpful to me in delineating the aspects of my writing that I have to clarify, expand, and edit. Most helpful of all were the detailed comments that Marjorie Senechal, one of the organizers, sent me after the conclusion of the workshop. She suggested two separate potential audiences that I should keep in mind during my revision, commented that I might have a typographical problem with the proposed title of my book, and listed a number of areas that she felt could be improved, such as certain conversational dialogues and character development in general. Finally, she suggested elimination of one character entirely, and plot revisions to make the story line more plausible.

Several other participants were sufficiently interested in what they saw and heard to ask me to send them the entire draft, and I now eagerly await their critical comments.

Patrick Ingram: I presented two pieces to the workshop, both broadly intended as windows into mathematics for non-mathematicians. The first was a non-linear piece of fiction, originally written as a contribution to a show at Harbourfront Centre in Toronto. This piece was written in the style of the Choose Your Own Adventure series of books for adolescents, popular in the 1980s. These books were characterized, in addition to their self-directed nature (and possibly heavy-handed moralizing), by the second-person narrative, which encouraged readers to live out certain alternate personas. My piece is intended to immerse the reader in the life of a mathematician, without necessarily explaining mathematics itself. Specifically, by capitalizing on the nostalgia and whimsy associated with the original series of books, I hope that this piece would allow the reader to side-step their existing anxieties about mathematics, since in the context of the narrative, they are themselves a mathematician. The critique of this piece offered insight into whether or not it could be re-worked, either in content or concept, for broader dissemination. The second piece I presented was a partially-written short story about a mathematician who makes a discovery which strikes at the foundations of mathematics, intended in part to convey to a lay audience some open problems in number theory and logic (specifically the Riemann Hypothesis and Gödel's work on incompleteness). In addition to the theoretical content, this work is also intended to address the reader's curiosity about what mathematicians actually do, albeit in a more conventional style than the first piece. Comments and suggestions on this idea, collected during the informal moments in the program, will prove useful in completing the project.

Gizem Karaali: I brought to Banff a draft of a story titled "A Mathematicians Dilemma." It is about a mathematician who is advanced in his years and his university is trying to convince him to retire and yet, he finds himself wanting to do math and teach math. We follow his reasoning along with him as he goes through the reasons for math education and one by one dismisses them. The reader is left to decide for herself what to think about the why question after we leave the protagonist to his thoughts.

During the workshop I have received much valuable and constructive feedback about the story. In particular readers suggested considering introducing or further developing some side characters, getting out of the head of the main character, and looking at the events through a second character's perspective. I believe each of these point me towards fuller and more real characters. I was also questioned regarding some of the implications of what I had insinuated in passing at various points. This points me towards being more explicit with my own intentions with the piece. In short, each and every piece of comment I received on my work was constructive and, I believe, will allow this story to be much more effective in the end.

I also brought to the workshop a very rough write-up, meant eventually to be the seed for a book proposal, which was dancing around a few too many ideas. The discussions about the book idea helped clarify for me my vision for the project. In particular I now am clear that I do not want to write a book that mainly focuses on mathematics education. This is not a sad or negative decision. In fact I believe that is already done very well and in an approach I am totally in agreement with in another recent book (by Jo Boaler in *Whats Math Got to Do with it*?) I therefore believe the focus will be on the actual doing of mathematics by the people of mathematics. I am still intrigued by the possibilities of incorporating some more ideas from and some of the structure of my recent math and zombies course. I believe the workshop discussions about genius and who gets to do mathematics further inspire and encourage me.

The workshop discussions on other participants work have also been rewarding and eye-opening for me. Once again I was reminded of the immensity of the task of the writer and the poet. Once again I observed the craft nature of writing and the sheer amount of work that goes into creating something that is of value to someone besides its creator. And once again I could see clearly that readers can help improve work at any stage.

All in all, I am delighted and honored that I had the opportunity to participate in the workshop. I made new connections with people who I now see as my friends as well as my colleagues, and I worked towards my own personal writing goals, all the while being reminded of the very collaborative and community aspects of the two life pursuits I find myself dedicated to: mathematics and writing.

Joe Mazur: I came to the BIRS workshop with a draft of fictional work about an ambitious high school senior in the South Bronx, her progressive math class, and her mentors. It is a story built from a few solvable mathematical riddles, and loosely based on a true-life story. An excerpt (a half-dozen of the 47 chapters) circulated in advance of the workshop led to many valued intelligent conversations, discussions, opinions, and constructive ideas that could not have happened without the intelligence and collegiality of our wonderfully

eclectic group of entirely egoless participants, all eager to hear and to know more about each other's projects. Several perceptive ideas for improvements came during the time of my workshop presentation, and others came as residual ongoing discussions, sometimes late into the evening. I believe that everyone gained hugely from the wisdom of our wonderful group. In speaking with others, I understand that the whole event was an outstanding success, and that everyone felt both a sense of accomplishment and an awareness of work to be done. I am a nonfiction author, in particular, an author of narrative popular mathematics. The work I presented at the workshop is my untrained attempt at putting together a work of fiction incorporating narrative mathematics skills. With one whole week devoted to critiques in writing, I came away with a comfortable list of ideas for improvements and an exhilarating sense of accomplishment, a feeling that would be hard to come by in my usual world of solitary writing.

Arturo Sangalli: I am a mathematician and the author of science and mathematics popularization articles and books. My latest novel, *Pythagoras Revenge*, [6], aims at communicating mathematical ideas and results to a large audience by weaving them into a suspenseful plot. I presented two pieces to the workshop and led an evening discussion on the use of fiction as an educational tool in mathematics and science.

"The elephant, the monkey and the laws of physics" is a short story about two physicists trying to explain a mysterious phenomenon. I put it into context with an introduction about the current Big Bang cosmological model. The story lightly derides the attempts of Big Bang supporters to patch up and save their theory whenever new data or observations call it into question. I took notice of the suggestions for improvements to the piece offered by the group. A discussion followed about the plausibility of alternative–someone called them "subversive"–models for cosmology.

The essay "Life after bad reviews" explores the feelings and possible reactions of authors after their book or article receives devastatingly negative reviews. The essay attempts to convince authors why things may not always be so bad; it offers some advice in the circumstances and ends on a rather optimistic note. Comments were generally very positive. I found the suggestions of venues for the publication of the essay particularly helpful; these included the Pen American Journal and Poets & Writers.

Marjorie Senechal: I brought a new draft of my play, *Pasteur in Alais*. I had begun it at an earlier workshop in this series but set it aside for several years to complete another BIRS-workshop-tested project, a biography of the mathematician Dorothy Wrinch, [7]. In this play I test the waters of fiction for the first time, but gingerly; though the fictional heroine of the epic poem "Mireio" by the Provençal poet Frederic Mistral (and of Gounod's opera *Mireille*) plays a leading role, most scenes are in fact fact, drawn from original documents. *Pasteur in Alais* tells the story of Louis Pasteur's tortuous efforts to halt the epidemic that was destroying silkworms throughout Europe, and with them one of France's largest industries. The experience turned Pasteur from chemistry to medicine, with results we all know. But though he saved the silkworms, he couldn't save French silk: the Suez Canal and the invention of rayon spelled the industry's doom.

In writing this play, I grappled with the problem at the heart of all creative writing about mathematics and science, whatever the genre: to tell a story without bogging down in technicalities, to convey mathematics and science without teaching or preaching. I brought the play back to BIRS to help me deal with that problem. I had written it as a "closet drama," to be read in the privacy of an armchair (with *Mireille* wafting from a CD), with end-notes filled with technical information that the reader needs to know. But Josy Fox, Robin Chapman, Don O'Shea and other workshop participants quickly saw what I hadn't seen at all: essential information (for example, the life cycle of the silkworm) can be conveyed on the stage through videos. Their consensus, to leave the armchair and go for staged readings, liberated and re-energized me. So did our discussions of everyone else's work. What a privilege it was to spend five intense days in the company of such dedicated, talented, and generous colleagues!

3 Non-fiction

Non-fiction includes popular science, biography, essays, educational writing, reviews, and so on. This genre was represented by the work-in-progress of Florin Diacu, Yossi Elran, Josy Fox, Katherine Merow, Donal O'Shea, Siobhan Roberts, and George Szpiro.

Florin Diacu: I brought to the workshop the first chapter of a book on social choice I intend to write. This chapter, entitled "Striving for gold," describes the experience of Olympic figure skaters Nancy Kerrigan and Tanya Harding before the Winter Games in Lillehammer as well as the outcome of the competition at the Games. The issue at stake is how the grading of the performances determines the winner. Behind this example is a serious conundrum: our social choices, including how the voting methods we use in political elections actually decide the winner. Behind the social implications of these procedures lie some interesting mathematical problems. Kenneth Arrow won the Nobel Prize in Economics by showing that there is no ideal voting method, but that some methods are "better" than others, in the sense that they better reflect the aspirations of the electorate.

I found the comments of those present at the workshop very useful. George Szpiro, who had already published a book on voting theory, [11], thought there is more room on social choice writing in the realm of sports, exactly in the direction of this project's first chapter. Other participants suggested interesting topics on this subject, such as the game of tennis, where matches are won when somebody completes two sets out of three (and sometimes, in men's tournaments, three sets out of five). But each set consists of games, which depend on points won. It can very well happen that a tennis player loses a match in spite of winning more points (or games) than her opponent. So there is a lot of room in analyzing these aspects of the game and coming up with a book that would interest to all those who like sports. I concluded that, should I ever pursue this project, I would definitely stir it into this direction.

Yossi Elran: I presented work on digital creative writing for math and science education that I and my colleagues are creating at the Davidson Institute of Science Education the Wezimann Institute of Science in Rehovot, Israel. Digitial creative writing is somewhat different from standard creative writing, mainly due to the vast diversity of tools and rich multimedia content available to the "writer". Crafting together videos, social media tools, embedded applets and fantasy in order to produce a coherent educational product is a rather complex process. At the workshop I presented one of our digital "storytelling" projects for math education - math-by-mail - and discussed the main issues and dilemmas we encounter throughout the creative process. I also presented preliminary work on a story designed to teach students in elementary school how to solve cryptarithms; the many helpful comments I received are sure to have an impact on our future work. These include the idea to continue the third-form narrative into the explanations and questions presented to the students, the need to maintain a coherent narrative throughout each e-booklet individually and the collection of e-booklets as a whole, and the re-arrangement of the order of the narrative to build up a step-by-step process of learning for the student. The impact of digital media on education and on standard creative writing was a discussion topic throughout the conference and the idea of free and open content for the benefit of all was reinforced. I am very thankful indeed for having the opportunity to participate in this workshop, learn from the other participants and contribute to the collective effort to make this a meaningful and substantial workshop for all.

Josy Fox: A freelance writer with a background in the professional theater, I write primarily short stories and personal essays. I chose for my submission to the BIRS workshop a personal essay that I had written several decades ago entitled "Medical Care: A Child's Right?" that encapsulated my outrage at how I was denied appropriate medical care during my upbringing. I wrote it many years after my break from my repressive past at the time that I had become aware of a family close to my parents whose 16-month-old son had recently died of bacterial meningitis. He too had been denied medical care in the same kind of authoritarian household as mine that practiced the well-known but little understood religion Christian Science. My purpose in resurrecting this essay and sharing it with the other participants in the BIRS workshop was to find a way to enlarge and enhance my message, in particular so that I could reach an unaware public in the United States that is now about to receive the benefits of the Affordable Care Act. Political pressure and lobbying behind the scenes has thrust bills before Congress requesting that no punitive action be taken against Christian Scientists if they decline coverage, which will not only weaken the pool for the majority but will allow others in faith-healing sects to try to avoid penalties. Determined at this juncture to get the word out in one way or another, possibly through exposure in op-ed pieces, I was transfixed by the BIRS workshop participants response. Their curiosity led me down another path. Almost as a cameo stage piece, I exposed, in the BIRS workshop setting, visceral details from my childhood and adolescence, and told about my break from the past. As they, apparently transfixed themselves by my memories, set me on a logical journey: the creation of

a staged monologue describing what I had vividly brought to life for them, depicting the inanity of a set of religious strictures that totally ignore scientific knowledge. And a more accessible revelation for the world at large.

Katharine Merow: I'm a staff writer at the Mathematical Association of America. My personal essays about my own mathematical experience have appeared in *Math Horizons*, [9] and *The Mathematical Intelligencer*, [10]. At BIRS I workshopped a piece aimed at conveying to the layman some of the excitement possible in the pursuit of mathematical knowledge. Borrowing stylistic elements of Antoine de Saint-Exupry's Wind, Sand and Stars, the essay portrayed mathematical giants Évariste Galois, Andrew Wiles, and János Bolyai as bold adventurers, sacrificing comforts and ignoring warnings en route to advancing the mathematical frontier. The group discussion made me more mindful of the "great man" narrative of mathematics and the arguments against perpetuating it. I was surprised by the heated debate that arose over the I-thought-unobjectionable sentence "I am myself no mathematician." I hope to increase the creativity of the writing I do for the MAA (and to see the work of other workshop participants in MAA publications!).

Donal O'Shea: I came to Banff because of you two, the organizers of this workshop. I did not know what to expect, but I'd known Marjorie and her work for three decades, and I'd admired Florin's and Philip's book, *Celestial Encounters*, [2]. The BIRS workshop was one of the best experiences of my professional life (and I think it might actually be the best). From a rather narrow, technical point of view, I came to the workshop with a long paper entitled "The Surprising Resolution of the Poincaré Conjecture." The paper was addressed to a number of different audiences: mathematicians, physicists, astronomers and historians of mathematics. Its theme was an extraordinary irony embedded in Perelman's proof of the Poincaré Conjecture. (In case, you've forgotten the irony, here is a reminder: Riemann was the first to realize that topology should be separated from geometry, and it was Poincaré who carried out his vision – but not before finding an very deep connection between the topology of surfaces and the natural geometry they carried. In separating topology and geometry, Poincaré founded the field of algebraic topology, and asked one of the most basic questions that one could imagine about three-manifolds, the affirmative answer to which became known as the Poincaré Conjecture. The question is purely topological, and no one, least of all Poincaré, imagined that its solution might involve geometry. Almost a century later Perelman settled the conjecture, essentially by showing the analogue of what Poincaré showed for two-manifolds – namely, that any three-manifold is comprised of canonical three-manifolds carrying a natural geometry.) Perelman, in effect, did for three-manifolds what Poincaré had done for two-manifolds.

However, my paper suffered from a number of defects that I could not figure out how to resolve. The exposition contained too much mathematics for much of some of the audience, and too much history for others. The affirmation and advice I received in the workshop broke through the impasse I had encountered. In particular, the suggestion that I break the paper into three papers for different audiences has not only suggested a course ahead, but given me the confidence to pursue it.

So, from the viewpoint of whether a publication will result, I am confident that the workshop was a success for me. But, there was another, and I think more profound, the way that the workshop affected me and, I think, other participants. When members of the mathematics community, and administrators (and I belong to both) think of our profession, we tend to separate research, teaching, and popularization. And we decry the public lack of understanding of what we do. This workshop, with participants who love mathematics but who would claim as their primary identities writers, poets, earth scientists, and journalists, opened up for all of us a more capacious view of mathematics, and suggested that those divisions are ones that we as a profession erect, and that they suggest false problems (whose solutions, therefore, are as useless as the attempts to find them). We should not seek to be understood, or to understand, but to be enjoyed, and to enjoy (and understanding will follow).

Siobhan Roberts: I brought to the workshop the final chapter from my biography of the Princeton University mathematician John Horton Conway, with the working title *Your Game, Professor!* (a fitting bookend to the first chapter of the manuscript which I brought to the BIRS workshop in 2010). With this excerpt I am ultimately seeking to unite and wind-up a number of threads established throughout the book, and leave the reader with an aesthetic sense of what the mathematical enterprise is all about. At this workshop, I received welcome reassurance that these aspects, and book's structure overall, are engaging and informative. It was

also helpful to learn that BIRS readers liked the slightly experimental approach of having the biographical subject, Conway, speaking in extended quotations that are separated in the narrative with a different font and different line-spacing, and styled almost at times in a conversation with the biographer, passing the narrative baton back-and-forth. All in all, the BIRS workshop provided invaluable feedback on the effectiveness of various literary devices I use in telling Conway's story, and on the state of the manuscript in general. I also found reading and critiquing the other writers' works to be inspiring and illuminating – especially the poetry! – providing a much needed fresh perspective as I head into the homestretch of writing and editing and readying the biography for production and ultimately publication in spring 2015, [8].

George Szpiro: For me the BIRS-meeting was one of the intellectual highlights of the year. As a writer of prose with no understanding of poetry whatsoever, this was the first time that I have been exposed to poets and poems. Hearing poets read their work, and listening to the workshop participants discuss and critique it, allowed me to gain an understanding of a totally new manner of imparting information. The workshop showed me that there is another manner in which to express oneself, a manner that not only conveys information but embeds it in a text that can express feelings and impressions. While I have always appreciated beauty in sculptures, music, painting and also in novels, it was for the first time that I realized that information can often be expressed just by implication, through the flow and the rhythm of words. Apart from learning about poetry, the workshop gave the participants an opportunity to interact with other writers. This is all the more important to mathematicians who are usually not exposed to public readings or to writers groups. For professional mathematicians, precision of words and definitions is practically the only thing that matters when putting ones ideas in writing. For authors who write about mathematics, the narrative is the goal. Hence the text, meant for a general readership, must be interesting and entertaining but, at the same time, must not compromise on precision. How to combine these two aims – especially in a field that is very complex and technical – is a skill that needs to be developed. It was a great learning experience to interact and exchange ideas with colleagues who are faced with the same problem. The only suggestion I would have for future workshops is maybe to include one or two sociologists or economists to the list of participants, in order to broaden the spectrum somewhat.

4 Outcome of the Meeting

The meeting will, we hope, result in the completion and publication of the varied works-in-progress presented here. It will also strengthen the community of writers that this workshop series has been building. Each workshop (since the first) has brought together a mix of new and veteran participants, a mix that strengthens workshop discussions and helps the community grow. Participants have stayed in touch year-round, commenting on further work, celebrating publications.

We are looking for a publisher for a second anthology (the publisher of the first, Klaus Peters of A. K. Peters, Ltd, has retired and the company has been absorbed by Big Publishing.) Should we find one, we will invite all the participants in all five workshops to contribute material.

We also hope BIRS will let us organize another workshop on Creative Writing in Mathematics and Science. You will hear from us again.

References

[1] Marjorie Senechal, Jan Zwicky, and Chandler Davis, eds, *The Shape of Content*, A.K. Peters Ltd., 2008.
[2] Florin Diacu and Philip Homes, *Celestial Encounters: The Origins of Chaos and Stability*, Princeton, 1996.
[3] Florin Diacu, *Megadisasters: The Science of Predicting the Next Catastrophe*, Princeton, 2009.
[4] Adam Dickinson, *The Polymers*, House of Anansi Press, 2013.
[5] Donal O'Shea, *The Poincare Conjecture: In Search of the Shape of the Universe*, Walker & Company, 2007.
[6] Arturo Sangali, *Pythagoras's Revenge: a Mathematical Mystery*, Princeton (reprint edition), 2009.
[7] Marjorie Senechal, *I Died for Beauty: Dorothy Wrinch and the Cultures of Science*, Oxford, 2013.
[8] Siobhan Roberts, *Your Game, Professor!*, to be published by Bloomsbury USA/Walker & Company, 2015.
[9] Katharine Merrow, "Math Therapy," *Math Horizons*, MAA, September, 2011.
[10] Katharine Merrow, "Math is My Femme Fatale," *The Mathematical Intelligencer*, 34, 1, pp 42-43, 2012.
[11] Goerge Szpiro, *Numbers Rule: The Vexing Mathematics of Democracy, from Plato to the Present*, Princeton, 2010.