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Cover Page Footnote

The interview was first published in Shifting Con- texts Stable Core: Advancing Quantitative Literacy in Higher Education, edited by Luke Tunstall, Gizem Karaali, and Victor Piercey, and published in 2019 by the MAA Press. It is reprinted here with the permission of the publisher.

On "Animals", QL Converts, and Transfer: An Interview

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Synopsis

In March 2017, Gizem Karaali interviewed Len Vacher, at the time the lead editor of *Numeracy*, the flagship journal of the National Numeracy Network. What follows is the extended transcript of this conversation, which ranges from quantitative literacy to computational geology, from transfer of learned content and skills to interdisciplinary collaboration. The interview was first published in *Shifting Contexts Stable Core: Advancing Quantitative Literacy in Higher Education*, edited by Luke Tunstall, Gizem Karaali, and Victor Piercey, and published in 2019 as MAA Notes Volume 88. It is reprinted here with the permission of the publisher.[1]

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[1] "On Animals, QL Converts, and Transfer: An Interview with Len Vacher," pages 225-237 in *Shifting Contexts Stable Core*, Tunstall, Piercey, and Karaali, Editors.

Readers may find more information about the book at https://www.maa.org/press/ebooks/shifting-contexts-stable-core-advancing-quantitative-literacy-in-higher-education. Also of interest might be this introductory note by the editors:

Tunstall, Samuel L., Gizem Karaali, and Victor Piercey. "Introducing MAA Notes #88: *Shifting Contexts, Stable Core: Advancing Quantitative Literacy in Higher Education*." *Numeracy* **12**, Iss. 2 (2019): Article 13. DOI: https://doi.org/10.5038/1936-4660.12.2.13

and two recent book reviews about the text:

Mast, Maura. "Are We at a Watershed Moment for the Quantitative Literacy Movement?: Review of *Shifting Context, Stable Core: Advancing Quantitative Literacy in Higher Education*, by Luke Tunstall, Gizem Karaali, and Victor Piercey, eds.." *Numeracy* **12**, Iss. 2 (2019): Article 14. DOI: https://doi.org/10.5038/1936-4660.12.2.14

MacInnes, John. "The Numbers We Need: Review of *Shifting Contexts, Stable Core: Advancing Quantitative Literacy in Higher Education*, edited by Luke Tunstall, Gizem Karaali, and Victor Piercey (2019)." *Numeracy* **12**, Iss. 2 (2019): Article 15. DOI: https://doi.org/10.5038/1936-4660.12.2.15

1. Introduction

While working on this book, I was delighted by the diversity of topics and contributors this volume would represent. However I also noted that some significant perspectives were missing. In particular, I believed strongly that the editorial team of *Numeracy*, the flagship journal of the National Numeracy Network, and the sole publication outlet exclusively dedicated to scholarship on quantitative literacy, should somehow be a part of this endeavor.

To this end, I proposed to Luke and Victor that I interview Len Vacher, one of the editors of *Numeracy*, and possibly include Dorothy Wallace and Nathan Grawe, the other two editors. I assumed that in editing the journal, all three would be quite overbooked and would not be able to contribute a full paper, even if they wanted to; however, perhaps simply talking away for a little while, they could share some thoughts. This was not a merely benevolent proposal on my part—I was quite keen on having an opportunity to chat with Len, as we had met in person only once in addition to exchanging emails through the years. I genuinely wanted to pick his brain on a bunch of topics, as I knew that he was someone with strong opinions, on QL and many other things.

But perhaps more relevant to this volume, I was simply curious to hear his thoughts on certain themes that repeatedly came up in this project. This idea was quite ambitious on my part, as I had never interviewed anyone before, nor (more importantly) transcribed an interview before. Fortunately, Luke, Victor, and Len were all on board.

After some initial discussion, we decided that I would send Len a list of questions ahead of time, and then we would talk on the phone, recording our conversation. With technical support from Vic Ricchezza of the University of South Florida (USF), and the Media Services team from Pomona College, Len and I were able to meet virtually on March 15, 2017. The conversation lasted over two and a half hours—we only stopped because it was past lunch time in Tampa, and I was getting worried that my recording device might fail somehow.

Below is the outcome, edited for clarity, grammar, and length (with Len's substantial input and explicit approval). We hope what remains interests you, or even better, challenges or provokes you.

2. The Interview

Gizem: Ok, let's start. As you know, the first question is about you. How did you find your way to *Numeracy*? How did a geologist end up being the editor-in-chief of a scholarly publication in quantitative literacy?

Len: Well it's a very long answer. It evolved over a long period of time. But before getting into that, I just want to say that, to me, mathematics and what I know now to be quantitative literacy (QL) have always been a part my geology. I've said many times that I really don't understand something in geology until I understand it mathematically. This is because we're dealing with metaphors and models all the time, and models are basically mathematical and logical (and I learned logic through math). That's always been the way that I've thought about mathematics, and I've found that that distinguished me from many of my colleagues, but less so as time has moved on. Now, it has been fifty years since I was in graduate school. I've seen quite a change in my field in some respects (math is increasingly more necessary), but not so much in other respects (still so many geology majors are put off by math, often from bad prior experiences). So it worries me for my field, especially with respect to QL (which is what math becomes, in my opinion, when it enters into geology).

But anyway, I've always had a bias toward understanding things in a mathematical way, although my core interest has always been in geology (since the fourth grade). I've been extremely fortunate in the people that I've met. When I was in college, I went to the University of Washington (UW) as part of their first honors class. And so I took honors mathematics courses. Although I was majoring in geology, I tried to take a mathematics course every semester (thinking it would be "good for me").

One of the semesters, I had Carl Allendoerfer. He was prominent in the MAA (president 1959-1960), especially in relation to mathematics teaching. He was chair of the UW Mathematics Department, so he promoted strong teaching in mathematics, especially in the honors track. I took two years of honors calculus, which was supposed to be equivalent to three years of "normal" calculus. I didn't understand (or even like) much of it, because it was so heavy on the proofs. But then I took a lot of logic courses over in the Philosophy Department, leading up to a graduate course, where mathematics really came in handy because everybody else was struggling with the logic proofs which came fairly easily for me—the undergraduate in this graduate course—because I had seen a pile of proofs in mathematics. Even though I really didn't understand the mathematics. But, you know, I didn't particularly want to understand that mathematics (I mean with all those proofs). I don't feel like I began to understand the mathematics until I began to teach hydrogeology, which came much later.

After my time at UW, I went to study geology for graduate work at Northwestern, which was very mathematically oriented, especially in statistical geology. Bill Krumbein, who revolutionized a lot of thinking about what counts as geology and founded the field of statistical geology, was at Northwestern at the time. In my time there, I was on an NSF graduate fellowship, and they all treated me quite gingerly. However, they immediately declared that I was mathematically deficient and that I had to take more mathematics and statistics. This had the effect of making me displeased with statistics ever since, or at least until recently when I learned about statistical literacy from Dick Scheaffer, Milo Schield, and Joel Best through my work with the National Numeracy Network (NNN).

So at the time Northwestern was at the center of the founding of low-temperature (sedimentary) geochemistry. This was from 1965 to 1970, and that was right at the beginning of aqueous geochemistry, as well as when geophysics was becoming entrenched in geology departments and ...

Gizem: And geophysics is very mathematical?

Len: Oh, geophysics is heavily mathematical, and geochemistry can be, to the extent it involves physical chemistry. So I took courses in chemical thermodynamics, and that sort of stuff, welcoming it because it was "just" (to me) calculus and graphs. And then what I found in my career ever since is that I can move from field to field within geology fairly easily.

What I've done mostly in my research career is in groundwater hydrogeology and physical hydrogeology, which are mathematical—it's the physics of flow in porous media. I never had a course in hydrogeology (not many existed when I was in grad school), although I ended up teaching it here at USF for over twenty-five years.

The reason I got into hydrogeology is an interesting story on its own. I was doing some stratigraphy work in Bermuda for my dissertation (completely nonmathematical) and I was the only geologist on the island. The Ministry of Public Works and Agriculture realized that they had fresh ground water underground. They came to me and said: "You are the only geologist on the island; tell us something about it." Well, I told them, I'm interested in just about all aspects of geology except ground water. I don't know anything about it. Well, they said, you've been mapping our rocks for some time; you can at least interpret what's coming up out of the well. So I agreed to do that, and one thing led to another. I was finishing up my dissertation when that happened, and that interaction with the Bermuda Government sparked a curiosity in groundwater. Coincidentally, I had an opportunity for an NSF postdoc position at Binghamton University (SUNY-Binghamton back then). I could choose to study anything I wanted to, so I chose to focus on the ground water of islands. How is it possible that fresh water can occur on some of those carbonate islands? I found some papers in journals of the American Geophysical Union—mathematical in nature—and so I gravitated to the subject. Near the end of the postdoc, I went back to the Bermuda Government and proposed: pay me for two years to come down and work with your engineers, with a budget to contract drillers, and we'll find fresh ground water. And they did, and we did. I was in my twenties. The project was successful, mainly because I talked to the drillers and, from their experience, realized what was going on—it all involved patterns relating to the mathematics of water tables and their gradients. All that was possible because of my mathematics background (and the experience and savvy of the drillers and engineers). I knew how to proceed as a geologist. I was able to get into the literature, and see and use the mathematics on top of the geology. That basically led to my entire career as a geologist.

What I've done—if you look into my geological work—includes geology and sea-level history of Bermuda, as well as ground water on ocean islands—small carbonate islands at various tropical and semitropical places, and a little in Florida.

So, what does that have to do with QL? In the so-called "30,000-foot view" it's a "forestructure"[1] of my career-long appreciation of the applicability and usefulness of mathematics, specifically because of its utility through transfer between contexts. More "down on the ground," here's the next chapter: I came here to USF after having taught large general-education geology courses at Washington State University (WSU). The time I was teaching at WSU was in the late seventies; I was there for nine years. The reason I came here was my interest in the hydrogeology of carbonate islands (not many of those Washington), to be close to the Bahamas, Bermuda, and so on. So whereas I taught introductory geology and sedimentary rocks at WSU, when I came here, I fell into teaching the first physical hydrogeology course in a series of graduate-level courses. This course, Physical Principles of Groundwater Flow, includes a lot of material using mathematics covered in multivariable calculus. The course was for graduate students, and we had the requirement that, to be admitted to the program, you had to have taken a year of calculus, and so I was quite comfortable thinking the students would be able to handle Darcy's Law, the Continuity Equation, and various other mathematically expressed concepts. But—and here's the point—what I found was that they didn't understand the mathematics that they had had, regardless of where they came from. There were students from highly selective liberal arts colleges, state universities, our own majors, and so on. They didn't have a clue (with a few exceptions, of course).

So I decided to teach a course that would address that problem, and we called it Mathematical Concepts in Geology. Although the course was more calculus-oriented than it is now, it was exactly what it said in the title: I reviewed mathematics concepts—things that I thought that grad students should be able to handle and have in their tool box. And I found the thing that worked for me was spreadsheets. We even got into finite-difference modeling using a grid on spreadsheets. So every lecture, every session, involved interacting in some way with spreadsheets that they would have to create by themselves. That eventually turned into a series of NSF grants, for about ten years,

[1] The term is from hermeneutics, the theory of interpretation. For a personal account, see [12].

where the theme was teaching using spreadsheet modules (including Spreadsheets Across the Curriculum [13]).

More to the immediate point of QL: I'd done that (Mathematics Concepts course) for five years or so when a couple of undergraduates caught me in the parking lot and asked if they could sit in on the course. I said sure, but it turned out, what they were really asking was to take the course as undergraduates. Now it's a graduate-level course, three times as expensive as undergraduate courses. They weren't interested in paying that, so they asked me to develop an undergraduate version of the course. I told them, I never thought I would see the day that undergraduates would ask for more math—at least not more mathematics in geology. They told me that they had heard about the spreadsheets and they thought that the course on math with spreadsheets would give them a competitive edge for employment. And so I made them a deal, saying I would develop the course if they got a petition that proves there is a demand for it. And they did. What they didn't know was that the chair (Mark Stewart) was a physical hydrogeologist; so, I would be teaching the core mathematics that he would use in his courses.

Gizem: So he was excited?

Len: Oh yeah, he was all for it! So that was the birth of the Computational Geology undergraduate course. (See [8] for more on this course.)

So, now switch to our (geology's) National Association of Geoscience Teachers (then, National Association of Geology Teachers) and its Journal of Geology [Geoscience] Education. The editor, Jim Shea, was of the opinion that, well, it's nonsense how introductory geology textbooks were devoid of quantitative content. So, unsurprisingly, his journal included a short column called "On the back of an Envelope" by Don Triplehorn with the intent "to promote the use of mathematics in the undergraduate curriculum." Well, Don retired. At that same time, I had cancer, and I was on leave for a long time. I wanted something to do during the recovery period, so I volunteered to take over that column. I renamed it "Computational Geology," and that turned into a series of short papers, each one on a mathematical topic set in a geological context. That lasted for about six years (1998-2005) with a total of about thirty columns. Most of them are available online (see http://nagt.org/nagt/jge/columns/compgeo.html). About a year or two after the beginning of that column, Project Kaleidoscope (PKAL) had a workshop at William and Mary on increasing the quantitative skills in geology courses.

Gizem: Just perfect for you!

Len: Yeah! And the organizers, Cathy Manduca and Heather Macdonald (mainstays of NAGT), asked me to give a keynote. In the meantime, through writing that column, I had discovered George Pólya and his book *How to Solve It* [6], and so I gave a talk to the geology professors at the PKAL session on Pólya. It went over extremely well. Jeanne Narum, who was the founder of PKAL, was particularly interested and intrigued by it, as she had never heard of Pólya. She lived in Northfield, Minnesota, which is where Lynn Steen lived.

Gizem: Small world!

Len: Unbeknownst to me, after producing *Mathematics and Democracy: The Case for Quantitative Literacy* [9], Lynn Steen wanted the working group to reassemble and reassess where to go after publication. So Susan Ganter, a member of the Design Team, was charged with putting a new group together to consider the question: Where do we go from here? Lynn wanted to bring in people from outside of mathematics. I don't know this for sure, but the Jeanne Narum–Lynn Steen connection has to be the reason that I was invited. Susan was the one who invited me. She and I were talking about this linkage a couple months ago (at the 2017 Joint Mathematics Meetings in Atlanta), and the only thing that makes sense to either of us is that she got my name from Lynn, and Lynn got my name from Jeanne. (Ah, the network!)

So Susan invited me to meet with this group in Philadelphia (July of 2001), and that's when I met Susan, Lynn, and Bernie Madison. Bernie was also new to the group at that time. That's where I met Dorothy Wallace, Wade Ellis, Jerry Johnson, Judy Moran, Janet Ray—many of the *Mathematics and Democracy* authors and Design Team. Before that meeting, of course, I was given some reading material, which included *Mathematics and Democracy*, and I looked up a book from the National Council of Teachers of Mathematics, a book on mathematics for the twenty-first century [1]. In it, there was a paper by Keith Devlin as well as a paper by Dorothy Wallace.[2] That paper introduced me to Dorothy, which led to my reading of her "talking to the animals" [14]. I think [14] is a paper that everyone interested in QL ought to read, even now.

[2] These are "The Four Faces of Mathematics" [2] by Keith Devlin and "The Many Roads to Numeracy" [15] by Dorothy Wallace.

At the time, Dorothy was well into a big mathematics across the curriculum grant, which I believe was the first of its kind.[3] Math Across the Curriculum is a big movement that began at Dartmouth and has been emulated and built upon in a lot of projects ever since. I remember being on the plane reading Dorothy's papers on the way to Philadelphia, and my takeaway was, excitedly, "Hey! I'm an animal! And they're going to talk to me!"[4] That's how it all started for me—I became a part of the group. And we (meaning, really, Bernie and Lynn) had a forum at the National Academy of Sciences ("Quantitative Literacy: Why numeracy matters for schools and colleges"), as well as series of workshops in the summers. I was part of the traveling band, including Bernie, Caren Diefenderfer, Jerry Johnson, Judy Moran, Rebecca Hartzler, and Dorothy[5] to some extent. We went to various spaces to talk about quantitative literacy and mathematics across the curriculum. And the upshot of the 2001 meeting in Philadelphia was that we founded a network consisting of a consortium of four established programs at Dartmouth, Trinity College (CT), University of Nevada-Reno, and the Washington Center at The Evergreen State University (WA), as described in the first issue of *Numeracy*, in a paper by Madison and Steen [5].

At the time that those workshops were happening (circa 2001 to 2005), I was also involved in geological research. The groundwater interest here in Florida and prior work in Bermuda got me into the field of karst—cave-ridden limestone—and after a series of things, I ended up on the board of directors (2006-2008) of the new National Caves and Karst Research Institute (NCKRI). When the acting executive director of the NCKRI wanted to visit here in Tampa, she asked to meet with our librarian Todd Chavez, because Todd was developing a karst portal of information and resources. I was invited to the meeting. Before the meeting, I made an appointment and went over to the library to have a sit-down talk with him. I opened the door to his office and I introduced myself. He said "Oh, I know who you are!" This surprised me. And he said: "You're the guy from the National Numeracy Network." I was thinking to myself: "Well, you must be the only person on campus who knows there is such a thing," and asked, "how did you know?"

[3] See https://math.dartmouth.edu/~matc/ for more information.

[4] A geologist thing: any erstwhile field geologist (wannabe or actual) old enough to remember geologists who personally recalled and told of when geology was all field boots, rock hammers, compasses, and burros is apt to consider "animal" as sort of an honorific.

[5] For future reference (in *Numeracy*), let the record show that Bernie, Caren, Jerry, Judy, and Dorothy are mathematicians, Rebecca is a physicist, and Len, of course, is a geologist.

He says: "I've been investigating." So I tried to explain to him what the National Numeracy Network was. And he says: "Oh, stop. I've been investigating. What you guys need is a journal."

And so we got serious there. We decided that we would grab Dorothy, and she and I—backed by Todd—would make a proposal to the NNN that we would do an online open-access journal. Dorothy and I presented Todd's proposal to the NNN in 2006, and the board of directors of the NNN thought for about five minutes (as I recall it) and said, "Yes, please!"

Gizem: "Yes, please!" That's cool!

Len: So within six months, we had another meeting at Dartmouth, with several potential associate editors, to figure out things as basic as what we're going to call it, how often we would publish, what the various roles might be, and so on. So we sorted all that out. And I believe it was at Dartmouth's expense. Dartmouth through Dorothy's convincing, and her example—explaining and demonstrating the meaning and value of quantitative literacy—has been instrumental in the formation and the maintenance of a lot of good things, involving numeracy (the field), NNN (the organization) and now *Numeracy* (the journal). But anyway, Corri Taylor, an economist and director of Wellesley's QR center, was on the NNN board at the time (and president soon after)—she's the one who came up with the name. We were throwing names up on the blackboard and she went up front and wrote "NUMERACY!" We said that's fine, except for the exclamation point. Then we came up with the subtitle "Advancing Education in Quantitative Literacy." And so then we set a target of a year out (January of 2008).

So it's been a long evolution. Geologist, Mathematical Concepts in Geology, Computational Geology, a series of columns, stumbling as one of Dorothy's animals into what became the NNN, and then becoming caught up in the mission (Todd's vision, really) of open-access publishing with *Numeracy*.

Gizem: In your story you're talking about how as you went through your geology career, you kept observing how mathematics allowed you to move within fields—it allowed you to understand things. But transferability is very hard to teach, and part of why you needed to develop those courses is because what the USF Mathematics Department was teaching was not transferring somehow.

Len: Yes, exactly. And I think that's really the crux of the problem. Let's say: I think quantitative literacy does not belong only in a mathematics department.

Gizem: I agree.

Len: Quantitative literacy is too big of a field to leave to the mathematicians to develop. Now, I certainly welcome the fact that many mathematicians identify with quantitative literacy and see the need for it. I really appreciate them. And I don't envy them their task, because I can see that it can be a battle for them.

But on the other hand, quantitative literacy is not going to work unless the rest of the academic world is involved as well. At least an equal amount. One of the things that's very exciting to me about the journal *Numeracy* is—and I've tried to touch on it in my "Grassroots" editorial [11] — articles that are resonating with the readership are commonly written by folks other than mathematicians. To me there's a difference between quantitative literacy and mathematics, which are reflexively conflated by many. For starters, using a spreadsheet as a metaphor, one is a discipline (a row), and the other is a transdisciplinary ability (a column). For another, and this is commonly said by my geology colleagues, one (yours) is the world of idealization and abstractions, and the other (ours) is the real, messy world (dare I say, the world of animals?). To my mind, and very simply put, quantitative literacy is about quantities. To me, a "quantity" is a number with units attached. Once units are attached, it's no longer math; it jumps out of its row and into the column of its context—it's in the land of quantitative literacy. A crass way to look at it is: mathematics is what is taught in mathematics departments, and quantitative literacy is how mathematics transitions over to what's used outside of mathematics departments. (Mathematical literacy is something different, I believe, and I don't feel qualified to talk about it at the moment.)

Gizem: But that then seems to imply that mathematicians can't teach QL, right?

Len: Well, it's difficult. It's difficult because the context is so important. You see, outside of mathematics is where the context experts are. You mathematicians have situated QL to a large extent with problems that you are familiar with as citizens. And this is part of the heritage that comes out of *Mathematics and Democracy*—sort of a legacy thing. There's an association with some people, in some people's minds, of quantitative literacy with social justice, for example. And you know, there's certainly a lot of connections between the contexts in which QL is taught in mathematics departments, and things that people are familiar with, such as financial literacy, voting issues, social justice, and so on.

Gizem: I see. I think what you're saying is: mathematicians have focused on a certain subset of QL, and maybe they can teach QL in the context of things that they as citizens have exposure to, but then we are either ignoring or not able to address QL in other disciplines.

Len: Unless you're working with them! Now there's a lot of work going on in mathematical biology, for example. Dorothy, for example, teaches what could be considered a QL course involving mathematical modeling in biology, taken by biology majors [7]. I think that's what she does. It includes differential equations—nonlinear differential equations in fact—so she has them program. I would consider that, and I think she would too, at least quantitative reasoning. So where I differ with a lot of the QL community is that I see different levels of QL, wherein the level has to do with the level of mathematics. I guess I'm not as sold on the notion that mathematicians can't teach QL (which you tossed to me) as there's a lot of QL being taught outside of mathematics. That's what I wanted to say!

And when we in geology, for example, or in geophysics or geochemistry, use mathematics to teach our subject, that's QL. We're using the mathematics to understand our context.

Gizem: We need allies, right? We need converts in each department to be able to do that.

Len: Converts!

Gizem: Converts. Because you really came to it through your own personal experience with and exposure to mathematics . . . but it also amuses me that your mathematical experiences were the type that do not seem to invite transfer. You took proof-based calculus courses. That really does not invite questions like "How do I use the divergence theorem when it comes up in geology?"

Len: I learned mathematics through trying to teach geology.

Gizem: That's very interesting.

Len: What those proof-based calculus courses did for me while in college was to introduce me to logic. I was actually envious of the students who took regular calculus because they were applying it.

Gizem: They could solve problems!

Len: Yes, and I couldn't. Until I was sitting in a hotel room in Bermuda trying to solve a flow problem, and it worked!

Gizem: Let me now ask you a question about NNN and SIGMAA-QL (or perhaps more broadly, the MAA). These are all organizational structures we created around the concept of numeracy. Do you see them as playing different roles, competing roles, or having some other form of relationship? How can they work together? How can the MAA members for instance help support the journal?

Len: Certainly there are different roles, different realities, and different opportunities. Here is my prepared list of ways mathematicians could contribute:

1. join NNN (currently for $30/year),
2. submit papers to *Numeracy*,
3. cite *Numeracy* references.

So for example, if you have a QL-related NSF grant, you can disseminate your findings in *Numeracy*. If you are moved to argue with a paper in *Numeracy*, do write a discussion paper, or if you read a good book, you can write a book review (those tend to get a lot of downloads, by the way).

Now more pointedly, SIGMAA-QL is a group within a mathematics society. You have to be a member of the society to be a member of the SIGMAA-QL. And the SIGMAA-QL is almost exclusively mathematicians. I'm a member of it, and I believe Milo Schield is too. But I believe we non-mathematicians make up a near-zero fraction. In contrast, the NNN is completely independent.

Gizem: It is discipline- and association-independent; it has economists, sociologists, psychologists, geologists, as well as mathematicians.

Len: Yes! Thinking again of the SIGMAA-QL: it has a place to meet. It's a part of the MAA, so with that comes the opportunity to have a couple of annual meetings and build a network. In my experience, however, the QL sessions themselves are not particularly highly regarded by the bigger organization.

Gizem: Sometimes. And sometimes there's so much going on that there is not much attendance, I've found.

Len: Dare I say it: I feel like the SIGMAA-QL—though a fine bunch of dedicated people, and probably very good mathematicians—is just sort of tolerated by the MAA.

Gizem: I wouldn't say that. I think the society likes to have several SIGMAAs, and they don't necessarily value one over the other; there are much bigger ones, which bring much bigger audiences to their talks, and SIGMAA-QL doesn't seem to bring as much. I think they don't really even have a way to favor one SIGMAA over another. But you are right: within the bigger MAA community, it is a very small group of people.

Len: I didn't mean favoring one SIGMAA over another, or maybe I guess I might mean that. I don't know; I just don't think that QL itself is valued as much as it ought to be within the mathematics community. What's valued in mathematics, it seems to me, is mathematics research. And that's where the intellectual effort goes; that's what PhD students are trained to do; that's where the preferred activities go that count toward advancement and so on; and mathematicians interested in QL are just not equal.

Gizem: I guess it's viewed as a service activity, as opposed to research or scholarship. It's perhaps considered a service to the community, to the country, or to students, but it's not necessarily viewed as intellectually stimulating. It's not even intellectually taxing, so it's even easy, some people might think, or it's not as important or challenging as mathematics research. For those of us who're trying to figure these things out, I think it's pretty tough, actually. But I agree with what you say. I think there's a perception that those who can't do mathematics, teach, right? And those who can't teach teach teachers, that is, think about pedagogy.[6,7]

Len: Yes! That's the SIGMAA-QL, underappreciated, in my opinion, but nevertheless advantaged on account of being attached to a major society. Now in contrast, the NNN is not attached to anything. The big thing that NNN has at the moment is a journal, of course. Its journal is completely paid for by the USF Libraries. It's open access, so there are no revenues coming.

[6] Apparently George Bernard Shaw actually says: "He who can, does. He who cannot, teaches."

[7] To clarify, all of these are what we have heard from others or read in between their dismissing comments. There are a lot of people who do not value pedagogical work, who do not value scholarship that focuses on education. GK and LV both want to explicitly state here that we strongly disagree with this perspective.

The good news about *Numeracy*, the journal, is the open access — it's available to anyone who wants to read it: here, across the U.S., and around the world. The bad news is that there is no revenue stream.

Back to SIGMAA-QL. It has mathematicians in it, and these mathematicians have the opportunity to meet at the annual meetings. They tend to publish their QL work either in *Numeracy* or in *PRIMUS*. *PRIMUS* charges $500 for yearly subscriptions to libraries, $150 for yearly subscriptions to individuals, or $50 just to "borrow" a paper for a day.

Gizem: Very different models.

Len: Yeah. Back to the NNN. It has very low membership dues, $30, but you don't get anything for it. The big thing is that it provides the journal, and what's more, because we're completely open in publishing—that is, we don't charge any page charges—we're free all the way around, in every sense of the word — except for peer review, of course; that's pretty rigorous (although aimed at improving the manuscripts with the purpose of helping authors produce stronger papers, not in rejecting manuscripts with the purpose of jacking up and touting a metric of rigor).

Gizem: No friction then, but also no revenue.

Len: Yeah no source of revenue. In my opinion, though, NNN has to remain independent. It can't be a subsidiary of a mathematical association, for example, because it's not a mathematics group.

Gizem: How about something like the Association of American Colleges and Universities (AAC&U), for example?

Len: That's exactly the right sort of thing, or maybe a library group. Basically what it comes down to is transdisciplinary education. Who does transdisciplinary education? And what's the purpose of transdisciplinary education? That gets to the issue of transferability. So go back to this editorial that I wrote for *Numeracy* about LEAP (Liberal Education and America's Promise) [10]. It had to do with the AAC&U taking on QL as one of its learning goals, and I set up a spreadsheet. I fundamentally think of disciplines as rows in a spreadsheet [horizontal silos], and things like QL as cross-cutting columns. I said that today, many words ago. It's in that framework that I think every member of SIGMAA-QL belongs in NNN. But the converse, of course, is not true.

Gizem: I agree.

Len: You asked how MAA members can collaborate. Well, some of you do submit some papers, review for *Numeracy*, and serve on the editorial board, but I think all of you should be members of NNN. Even if you don't get anything for it. I think you should think of it in terms of a charitable contribution.

Gizem: I may have let my membership lapse this year. Maybe I will renew my membership after we finish this interview.

Len: Well, I think mine has probably lapsed, too.

Gizem: There you go. You and I should go and renew our NNN memberships!

Now I also asked you as part of the pre-interview preparation: "Are there articles from *Numeracy* that have changed or transformed how you view quantitative literacy? How so?" I like what you wrote: "Yes. They all have. Especially the ones that I have written." And of course, you're right, the peer review process helps you evolve even more. As I edit the *Journal of Humanistic Mathematics*, I am deeply involved with each individual paper, and each of them adds something to the way I think about mathematics. About mathematics for me, and about numeracy for you, right?

Len: Absolutely! I'm especially intrigued now by the international dimension. The more I read about what's going on in QL outside the United States, the more I'm thinking that it might turn out—from the outside looking in—that the emperor has no clothes, with regard to QL in the U.S. That is, it could be that more exciting — more enduring — advances are being made in QL outside the U.S.

Gizem: Well, that doesn't necessarily mean the emperor has no clothes. That might mean that we need a more diverse wardrobe, right? I too was thinking that both SIGMAA-QL and NNN are very much based here in North America. And there are organizations around the world and many researchers too, like in Australia and Israel, for instance, who care about QL. I was thinking about contemporary Israeli research on adult literacy and numeracy, for instance. So there's work going on that we may not be aware of. In this connected world, maybe we should be better connected.

Len: Exactly. I feel the same way. You asked what's been achieved in *Numeracy*. I think one thing is a steady stream of papers from outside the U.S.

For example, counting the issue coming out this summer, here is the run of annual numbers of international papers, starting with volume 1 (2008):

$$0, 0, 0, 1, 3, 5, 2, 1, 4, 3.$$

And here's the provenance: South Africa (4 papers, 3 author-sets), Australia (3 papers, 3 author-sets), England (4 papers, 2 author sets), Canada (2 papers, 2 author sets), Israel, Scotland, Germany, France, Switzerland, Austria.

Gizem: Excellent!

Len: They consistently make me stop and think. We can learn from these people.

Gizem: Yes, maybe more international collaboration and cooperation. And for us to listen a little bit more, right?

Len: Exactly, exactly.

Gizem: We have to learn before we can possibly even contribute. Who knows?

Len: For us animals, it's a whole new, international ecosystem to understand.

Gizem: Yes, let's talk to them, or let them talk to us!

Len, I think *Numeracy* is unique. Even though there might be other organizations and other research groups and other practitioners, thinking about these questions around the world, the journal *Numeracy* is unique in that it's the only outlet that I know of that is dedicated to scholarship in numeracy. Is there anyone else?

Len: Well, there isn't that I know of.

Gizem: So you will be flooded soon.

And we have a few more questions. So this was a question that Luke wanted us to talk about. Do you believe there is a core ethos of QL, and if so, do you believe that it's stable?

Len: Well, let me read you what I wrote. I start with "I'm not comfortable with the word 'ethos.' I have core values— rationality and competence— and I associate QL with both of them. And yes, that core is quite stable."

But I don't think that's what you, or I guess Luke, wanted. Now that I know the question is coming from Luke, I think I can guess where he's coming from. But anyways, rationality and competence are what I think QL is all about. See, in my Computational Geology course, I've gone over entirely to word problems now. Word problems almost by definition involve higher-order thinking. You actually have to take apart a problem, so you're analyzing, working at the individual parts, putting them together, and synthesizing. It's not in my course to the point of the highest level of Bloom's taxonomy, where it's metacognition, but what I want to have my students do in Computational Geology, through all those word problems, is to operate at steps 4 and 5 in Bloom's Taxonomy. As necessary, they reach down to levels 1, 2 and 3, in their mathematics, and transfer that into the context where they're working at the higher levels. So if they can do that, if they can reach into their calculus, or into their algebra, or their discrete mathematics, if they can do that, then I consider them competent. That's what I'm looking for. That's a large part of operational quantitative literacy to me (the rest concerns communication).

Gizem: That's interesting. So you're thinking that the lower levels are skills that you can retain after successful completion of early undergraduate mathematics courses, possibly, but then in some sense, you're saying that the higher levels have to be addressed in context.

Len: You guys can do the higher-order thinking for your majors, within the mathematics context or the contexts you're familiar with, such as financial literacy or health numeracy, but I don't think there's many mathematicians out there that know enough geology, for example, to be able to do it within a context involving the real Earth.

Gizem: Of course. We don't have the expertise. This comes back to the need for converts.

Len: Right. So I believe QL, as a course, ought to be taught in every department, including mathematics. And I would hate for you not to teach students algebra or calculus. We need for you all to do that. Even if it means that we have to follow you and do the extra work of demonstrating to the students why they should have learned it better. They learn it better the second time around, from someone else. You all are running interference for us.

Gizem: Well, I like teaching calculus. I insert some history into it—some human context. But of course my real context is the mathematics itself. So for me there are difficult things and interesting things, and even contextualizing

the history gives me a deeper sense of mathematics, and why people did what they did. But then, of course, it is again within the mathematics department. It's not necessarily allowing, or helping even, the student to transfer that to their physics classes, for instance, unless my examples are a little bit related. It's hard. But then those problems are very hard to assign to students, as well, because they don't actually like the "real world application" problems.

Len: Well, not if it is in the mathematics department, because it doesn't have the same texture. In my experience, even reading Pólya's book on trying to apply mathematics to circumstances outside of mathematics, they're so contrived, or they're so out of real context. Where it really works for me in geology is when the students are so engaged in the geology that they pick up their mathematics and they don't know they're doing that. What's nicer still is when they don't have to stop to be taught the mathematics just-in-time, but in my course, I expect to do that (just-in-time teaching) and it works out fine (not many surprises anymore).

Gizem: That's kind of how I learned linear algebra. I didn't learn linear algebra in college. I did learn how to multiply matrices of course, and even how to diagonalize them, but I had no idea what I was doing or why. But when I started learning representation theory in grad school. I thought, oh my goodness, this is so beautiful! And then I had to go back and learn linear algebra to pass an exam, and then I realized that everything I liked in representation theory was linear algebra. So I learned linear algebra through representation theory It is an interesting phenomenon that you can sometimes feed people things without them noticing what's going into their diet.

So we talked quite a lot about some of these questions. We also just started talking a little bit about AAC&U's LEAP initiative and all their learning objectives. There are several literacies they consider in their rubrics: information literacy, digital literacy, media literacy, along with quantitative literacy and science literacy. Maybe these all come back to transdisciplinary education.

Len: Yes. Yes. I don't really know much about those other literacies though. But QL, especially logic and discrete mathematics, is a precursor or fellow traveler with digital literacy, I would think. And QL is necessary for media literacy, I would think. And I suppose I would situate QL as a subset within information literacy but I'd have to consult Todd on that one. I associate information literacy with information science and information science with the library. I think the AAC&U is possibly a happy home for QL. I think the library, in general, is a happy home for everything that is transdisciplinary.

I'm really disturbed by the silos, though I can see why the university needs its silos. On the other hand, it seems to me, especially when the university is thinking about what to do under the heading of promoting student success, it's those sturdy columns—the transdisciplinary columns—that lead to successful alumni, I believe, more so than those rows where one learns more and more about less and less, in my opinion. I guess then as a veteran of major research universities, I might be seeing benefits of a small liberal arts college.

Gizem: This is interesting too. I'm in a small college and we don't have a separate honors college. But I can see how the library works in my context. This may be very context-dependent, based on the institutional context. For instance at Pomona we have an Interdisciplinary Studies Program, which doesn't exist actually—it's just a code that we use for first year seminars. The first year seminars are supposed to center on critical inquiry; they're taught by specialists from across the disciplines. It's in fact pre-disciplinary, before you move into the disciplines, or above disciplines, across disciplines, so the word inter- is not quite right, and trans- is much better. We would never be able to pass one here, in our current climate, but it seems that a QL requirement, as part of a set of general literacies requirements would also belong, in my institutional context, in such a formation, in such a construct.[8]

The library's role does not always fall within education in all institutional contexts. A lot of places just see the library as a research resource. So the way you see the library as a transdisciplinary column won't make sense to some people. Now it does make sense to me, because I also work closely with some of our librarians here, and our librarians are very much interested in instructional support. But I don't know if that's really common. You're at a big research institution, so I'm pleased to hear that your library seems like a welcoming place for it, but then again it was Todd Chavez who was the person who said "You need a journal!"

Len: Yes. He is a unique person, of course. But we've got to find somebody. We've got to find some unit that crosses disciplines.

Gizem: QL is not a disciplinary issue, it is transdisciplinary. I totally agree with that.

[8]Claremont Graduate University has a transdisciplinary studies program: https://www.cgu.edu/why-cgu/transdisciplinary-studies/. GK has taught a course on humanistic mathematics there!

So we've talked a bit about *Numeracy* contributors who are mathematicians, and contributors who are not mathematicians. We've talked a bit about mathematicians' blind spots. And we've talked about why we desperately need to have converts from other disciplines. Now I wonder if you have anything you can say about blind spots for non-mathematicians. Have you noticed any of those? Let me see what you wrote for that. You said "no comment on blind spots." Are there any things that you would like non-mathematicians to improve on?

Len: I would like them to recognize when they are doing QL. And to publish about it.

Gizem: So maybe be more aware of the reach of QL?

Len: Well absolutely. I think one of the big problems is that—I see this in particular in sciences, in engineering—they've all had calculus, so *ipso facto* they all must be quantitatively literate. I think that's fallacious of course. So there are a lot of requirements in universities and colleges, something they call quantitative reasoning requirements, which are satisfied by things like a calculus course; that's a conflation I referred to many words ago in the context of a row vs. a column. I want people—including engineers and scientists—to recognize that reasoning quantitatively and QL are something separate from routine calculus and algebra. In other words: scientists, engineers, economists, social scientists—many of them—are actually teaching quantitative reasoning in many of their courses. If they are consciously explaining, contextualizing and using the relevant mathematics, creating and using word problems, doing labs or research projects requiring the student to figure out the math to use (rather than plug into a given formulaic equation) and not talking around the mathematics or (falsely) assuming that the students already understand it just because they've had calculus, for example, they are teaching quantitative reasoning.

Gizem: That's kind of my first paper in *Numeracy* [3]. I was assigned the task of teaching this calculus course to students who actually did not want to take calculus, but the course was required, especially by the psychology department to basically weed people out, because it was the most popular major at the University of California Santa Barbara. The person who had developed the course talked to client departments, figuring out that what they needed was transfer and skills with word problems. Since they were also possibly going to have premed students as well, they needed to have "Calculus" on their transcript.

So he developed a course which had calculus in its title but it was really about solving problems. And that's kind of how I got into all of this QL business. Because when I was teaching that course, I realized maybe this is what they need to learn—how to solve problems—and the mathematics content is not always the most significant. That was my first foray into QL.

Len: I think what you said underscores one of the big problems we do have in science. We have it in geology. There are a lot of departments that require calculus because it's a weed-out course. Simply because it's a way of establishing whether or not the students are degree-worthy, and then in their subsequent courses it's immaterial.

Gizem: They don't use it.

Len: So why take it?

Gizem: Very good point!

What shall we talk about next? How about: What do you see as the next steps for *Numeracy* and the QL movement? We talked a bit about it but maybe we might want to focus on it. What has proved to be too difficult to overcome? You wrote here: "Travel to a meeting that's not already on the calendar." I like that one!

Len: Yeah, it gets back to the structure of NNN and SIGMAA-QL. I really don't know what the future of NNN is going to be. I think it has some difficult structural problems, but I think it's necessary that there be some sort of an organization which is not housed in a mathematics department.

Gizem: I agree.

Len: I don't see us as partners so much as fellow travelers. And I think we should be aware of each other's work, and inform each other, but there are some fundamental differences and in a sense barriers that can't be crossed. Barrier is not quite the word. Perhaps I mean boundary (and possibly a permeable one). One of the things I was stumbling around with is the beauty side of mathematics. And I think your position is that that belongs more in mathematical literacy. I'm ok with that. But I was stumbling around because I didn't realize that that was your position, but now I remember that was in that article that you wrote [4].

But I guess the point I want to make now is that I was in this game for about twenty years before I began to realize any of that. So that, what you're talking about, that side of mathematics, is really highly evolved,

and yet, many of us who really value mathematics, and use it and want to know more about it, we never reach that level. Or we reach it only in our old age.

Gizem: Well, it's big, right—mathematics is big? The world is big. One needs a little bit more—I guess—perspective...

Len: Yes, but there's a corollary. You have to keep it in mind when you speak of us as converts. We're not mathematicians. We're not going to be converted to be mathematicians. We don't want to be mathematicians. It might be expecting too much of many of us to appreciate the "beauty" side of mathematics, or the many nuances, the way you all wish we would, or to the level that many of you might think necessary to be qualified to speak usefully about mathematics.

OK, so let's get back to Luke's question about the ethos of QL. What I said there...

Gizem: Values, you said, reason—the age of reason, that comes to my mind—OK you said: rationality and competence.

Len: Yeah. OK, next. You might mean purpose. In that case, I would say that I view QL as having a communitarian purpose (in the sense of Amitai Etzioni), and to the extent that it serves individual purposes, that's so that the individuals can better serve the common good. You know, communitarianism, that's where I think QL is.

Gizem: It's very interesting. In our volume we have a paper which argues that the QL literature has been very much posed within the language of individual success and individualism, and they want to push back on that and bring out a community aspect of QL. And so it's interesting that you raise that point here, that you think for you internally QL is already communitarian. Could you open that up a little bit? That would be very interesting, because in particular we have that paper that argues that QL literature has been often individualistic. Like individual success, like people will not be fooled by others trying to trick them by numbers, and then you will know who to vote for because you as an individual will know what is in your favor... In other words, QL is promoted, according to these authors, in such a way that prioritizes individual outcomes (as in: a quantitatively literate individual would not be fooled by others trying to trick them with numbers).

Len: Actually, I would say that that position—not to be fooled by others trying to trick them by numbers—is a part of my communitarian take on QL. That's because to me, communication is a hallmark component of QL. For me, problems often are underpinned by semantic difficulties impeding communication of the kind necessary to build a community and have it prosper. Oftentimes, the miscommunication is not at all intentional; it's just that people are often lousy at it, especially when it comes to quantities (quantitative material). To me, communication is the "L" in QL. Communication is one of the corners of a triangle representing the QL triad. Calculation is another one, and logic is the third. You can see a portrayal of that in the paper [8] about my Computational Geology course. The QL triad is Figure 3 in that paper. One of the associated principles (see that same figure) is "words underperform our thoughts."

That reminds me of something else that I want to make sure to get in. Can I get it in?

Gizem: Sure.

Len: It's about how SIGMAA-QL people can help *Numeracy*. You know I am a member of SIGMAA-QL and I lurk on the listserv, and very rarely drop in. Very rarely. Because I don't want people to be aware of that, because I'm an outsider. But I'm very fascinated by the discussions. And I'm really annoyed that the discussions end there. In the stereotyping that routinely goes on about mathematicians, I think, OK, they do talk a lot.

Gizem: Oh yes we do. Too much talk and no work.

Len: Oh, I wouldn't say that, but how about writing something? You may remember that we had a paper a couple issues ago by Ander Erickson questioning whether QL is one of those things to be left to the experts. Apparently this paper has created quite a stir in some departments, I've heard. Well, we have our first discussion/reply on this paper.

Gizem: I will need to check up on that, because the people who brought up this idea that QL has been too individualistic have also brought up the idea that, oh, maybe, not everybody has to be QL experts. They were also espousing the same idea.

Len: Well, that's what made me think of it. A mathematics person, who is an exceptionally readable writer, wrote a discussion piece, and I accepted it.

Just two days ago, I sent it to Ander and said I would like to publish a reply about the same length, two pages, and this would give you an opportunity to expand on your views. And he got back to me and he was thrilled. So we're going to have our first discussion and reply. (Ander's reply arrived in May, and it is in press now).

So you know, I think I would like to—through you now and this interview—to take this opportunity to charge the people who are discussing issues on the SIGMAA-QL listserv...

Gizem: To write them up!

Len: And, if it has something to do with a *Numeracy* paper that you're discussing, write a discussion and, we'll offer the original author an opportunity to write a reply. We're in our tenth year, and no one's done that until now. And you know, I don't think people realize that they can do that. But it's there in the instructions to authors.

Gizem: I unfortunately should close this out now. Thank you, Len. I'm very honored that you took the time, and you've been pretty open. You were also quite gentle with me about mathematics and my feelings, and I appreciate that.

Len: Hey, I just want you to know that I've liked and admired every mathematician I've met. Working with first NNN, now *Numeracy*, and knowing many in the SIGMAA — that's been a pleasant final phase of my career. Mathematicians have all been nice to me. I especially have liked it when they talk to us animals. Or, shall I say, so long as they let us get a word in edgewise. So thank you for giving me this generous opportunity.

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