Questions not Answers

Richard Hoshino, Quest University Canada

Why do so many children lose their natural curiosity when they grow into adulthood?

This question was asked by Amanda Lang, the co-anchor of the daily *The Lang & O'Leary Exchange* on the CBC News Network. In her recent book, "The Power of Why", Lang shows how the ability to ask the right questions is vital to innovation, creativity, and success.

So why do students lose their innate curiosity? The author argues that our modern-day education system is largely to blame, where students are fed facts and formulas, and are not given the space to take risks, make mistakes, and explore the questions that are pertinent to their lives.

In elementary school, students learn that getting the right answer, rather than asking the insightful question, receives the gold star. In high school, students learn that they can obtain high marks only if they avoid making mistakes, thus educating young people to become less creative. Such a system causes students, especially those at a university, to believe that questions aren't important: instead, what matters are marks, and you only get good marks if you know the right answers.

She ends the book with the following hypothetical story:

> *Imagine you could design a university from the ground up. Not just the campus and the buildings, but also the classrooms and what happens inside them. What would the place be like? What would students do there, and what would they take away?*
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> *The first thing you might do is scrap the model of instruction that's prevailed for hundreds of years, wherein a professor lectures at the front of the room and students take notes. That model is, after all, an artifact of a time when printed material was scarce, so an instructor's job was primarily to tell students about the book he'd read (or written). Since you're changing all that anyway, you might also want to toss out the notion that information should flow in just one direction. You might be swayed by all the new research on how we learn and process information, and opt for highly interactive courses, where expert guides are standing by but students are also allowed to explore and make discoveries.*
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> *You might design a curriculum that aims to get students to drill down, instead of skimming along the surface, and to that end, perhaps you'd decide to organize things so that students could focus on just one subject at a time rather than juggling five or six. You might, reflecting on your own experiences and all the things you "learned" but didn't retain because you weren't really all that interested in the first place, let students shape their own curriculum to some extent. You might even decide <u>they</u> should be the ones asking questions, and that those questions should dictate their academic path because, at the very least, they'd be studying things they cared about...*

> *The real point of a university, you might decide when thinking about how to build one from scratch, isn't to hand out degrees. The point is to encourage and foster certain traits, like curiosity, so that students want to keep exploring and learning even after they leave. Your hope would be that by then, they'd be fearlessly curious and hooked on learning – not only because that would make their lives better but also because it would be a pretty big contribution your university could make to society: cranking out innovative thinkers…*
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> *And the result – the innovative place I've just described – actually exists. Nestled in a valley at the foot of the Tantalus mountain range in British Columbia, Quest University [Canada] aims to teach young adults to think for themselves.*

In February 2013, I moved to Squamish, BC, to become the third mathematics "tutor" at Quest University Canada. In my short time at Quest, I've discovered that post-secondary math education can be radically different from my own undergraduate experience of memorizing formulas and regurgitating proofs without understanding their context or purpose, where professors squashed my curiosity by monotonously lecturing at us through the paradigm that viewed information transfer as the only method of learning, rather than speaking with energy and passion, incorporating multiple teaching strategies, or empowering us to construct and create knowledge for ourselves.

So what is different about this start-up independent liberal-arts university, and what can we learn from their unique approach to undergraduate mathematics education?

Quest students spend their first two years in a broad Foundation Program, where they take 16 required courses that span the arts and sciences. After completing their Foundation program, each student poses a personal Question that directs and shapes the final two years of their undergraduate studies. Among these 16 required courses is a "block" in Mathematics, where every student engages in an in-depth study of the subject, for an entire month: three hours a day in class, with five hours of homework each night.

Each course at Quest is taught using the block format, where students take a single course each month, rather than juggling four or five courses each semester. This focused approach forces students to concentrate on mathematics, a subject that for many evokes feelings of anxiety and fear. The students can't procrastinate by working on "other" courses, and so they can confront these feelings of anxiety head-on; indeed, they have to.

Since every student is required to take a Foundation math class, a natural question is what type of math class should be offered. Should this math class be a broad survey course, or perhaps a "service" course such as Calculus or Linear Algebra to prepare students for future math courses, as well as courses in biology, economics, physics, and chemistry?

Quest's answer is neither. The goal of the math foundation course is to introduce students to the ways in which a mathematician asks and answers questions about the world. Instead of providing an overview of current knowledge in mathematics, the goal is to introduce the approaches used by the discipline, and to expose students to significant mathematical ideas and moments – which *they* create and discover, based on their questions, on the issues that matter to them.

By the end of a Math Foundation course, Quest students should understand that mathematics is a process of abstraction of quantitative and spatial experience into a mental model capable of analysis. They should recognize and be comfortable working with the three most common modes of mathematical discovery and inquiry: *symbolic* (algebra), *numeric* (arithmetic), and *visual* (geometry). They should have developed a proper attitude toward solving mathematical problems: question formulation and clarification, experimentation, inference, use of resources and technology, refinement, attention to detail, and final articulation. And they should be able to apply this knowledge to communicate mathematics effectively to colleagues and client groups.

In other words, Quest does not use Calculus as a "gatekeeper" course to weed students out of their university. Instead, the vision is to have the mandatory math foundation course be a "gateway", where students, regardless of their areas of interest, realize that mathematics can help them understand the world, their world, in a more meaningful way.

The university has clearly recognized that mathematics needs to be distinguished from "quantitative skills" such as algebra and arithmetic, and has established a Learning Commons where upper-year students serve as peer tutors to help students struggling with elementary math skills. It is the responsibility of the Learning Commons to help students prepare for courses in other disciplines, rather than requiring those teaching the Math Foundation courses to fulfill this role.

Since the Foundation block is intended to embody a mode of inquiry rather than a specific set of content, several different Math Foundation courses have been offered at Quest. These include the following:

> **Spherical Trigonometry:** *Born from the study of celestial motions in ancient Greece, spherical trigonometry became a standard part of the repertoire of mathematicians, astronomers, and navigators until it was almost forgotten in the late 20th century. This course will take a primarily mathematical view of this beautiful subject, bringing in astronomical history to provide context. Topics include the properties of a spherical triangle, both right and oblique; Menelaus's Theorem; the Rule of Four Quantities; the Law of Sines; Delambre's and Napier's analogies; duality; areas and the spherical excess; relations to plane trigonometry; applications to polyhedra; and the role of stereographic projection.*
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> **Visual Mathematics:** *The human sense of sight has played a fundamental role in shaping the evolution of mathematical thought throughout the ages. Whether used for understanding mathematical patterns, solving challenging problems, or creating beautiful and fascinating images, visual ideas and methods are fundamental to the insight and intuition at the heart of mathematical thinking. In this course we expand our senses of perception as we tour a variety of mathematically rich visual vistas, from proportion and mathematics in art, to the rich patterns of fractals, to the mystery of the shape of the universe.*
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> **Symmetry – Patterns and Structure:** *Most of us already have a good sense of what symmetry is. The painter looks for balance and composition, the chemist thinks about atomic structures, the architect sees the division of space, and the musician hears counterpoint. Symmetry is the mathematical principle that unites these different perspectives. In this course, we will develop the language of*

symmetry from scratch. First we will build the Platonic solids (we'll need origami), and using simple ideas such as rotation and reflection, we'll learn how to talk about patterns. We'll study how the same concepts appeared in different times and places; for example, the ancient Greek understanding of symmetry reappeared in the architecture of Spain's famous Alhambra and was reinvented by 20th century mathematicians. By the end of the course, we'll understand how the mathematics of symmetry can inform us about arts and sciences today.

Mathematics: A Historical Tour of the Great Civilizations: *Mathematics is the oldest of the liberal arts, yet few are aware of its vast and subtle influences on our lives. It is a practical tool, to be sure, but also it has played a major role in shaping who we are and how we think. Historically, mathematics has helped end old regimes and modes of thought, and constructed new ones. This course takes a grand tour through the dominant mathematical cultures: ancient Babylon and Egypt, ancient Greece, medieval Islam, pre-modern China, and Europe today. We discover how mathematics shaped, and was shaped by, the people who practiced it, how it interacts with worldviews and alters ideas.*

Mathematical Problem-Solving: *This course is about the heart of mathematics, a collection of beautiful problems connected together in unexpected ways. The problems are chosen from a wide spectrum, ranging from recreational puzzles and brain teasers to contest problems. Students will also read a math novel, in which the main character learns the art of problem-solving and through that process, develops insight, imagination, confidence, creativity, and critical thinking. Students will use this novel as a springboard to reflect upon their own mathematical journey and explore how problem-solving principles and techniques can be applied to address some of society's toughest challenges.*

To illustrate the power of teaching mathematics in this way, I'll close by sharing the story of one of our international students, who took Mathematical Problem-Solving with me in February 2013. This student had a traumatic experience of mathematics, including being subjected to repeated physical violence as a junior high student, receiving five lashes for each mistake made on a daily morning math quiz. When she arrived at Quest, she discovered, to her horror, that she had to take a course in mathematics. (Perhaps if she knew this requirement, she would have chosen a different university!)

With much trepidation, this student enrolled in Mathematical Problem-Solving, and discovered to her surprise that the course did not emphasize the tedious manipulation of algebraic symbols, but rather focused on developing general problem-solving concepts such as finding isomorphisms and exploiting symmetry, and using the ideas to model real-life problems relating to social justice and environmental sustainability. And with no other course to focus on, this student had no choice but to confront her dislike of mathematics, and spent numerous hours, every night, to master difficult course material, and learn how to write up formal mathematical solutions in her second language.

As the tutor for this course, I could see this student's confidence improve day by day, and this was clearly evident, whether she was sharing her problem-solving insights and ideas in front of her peers, or submitting a flawless solution to an assignment problem that originally appeared as a question on the International Mathematical Olympiad.

For the final project in the course, this student came up with an innovative Roommate-Matching Algorithm, inspired by her experience of being matched with some un-ideal roommates during her first week at Quest. She devised an idea revolving around students' "preference" scores and "profile" scores, based on categories such as cleanliness and study habits. From there, she led three classmates in determining the mathematics of how this information could be applied to figure out how to optimally match students to residences. She was so convinced of the potential of this project that I arranged for her to give a presentation to our university's Director of Housing, in March 2013.

Three months later, this Director of Housing wrote a Facebook post to the 225 students entering the university in the fall:

> *Ever wondered how we assign your housing at Quest? Check this out!*
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> *Like many things at Quest, we do it a bit differently. Our goals this year was to expand on our already hands-on, human process to get the best possible matches, and be as inter-disciplinary as possible in our thinking.*
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> *We are using some custom algorithms written by one of our math tutors, based on Nobel Prize winning pattern matching theory, to help us find good matches for your room-mate and floor preferences. Remember that long form you filled out? Here is where the data ended up!*
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> *Building on a student class project, we redesigned the housing application this year to use this new matching theory approach. We wanted to not just know what your preference was, but how important it was to you. Instead of just randomly assigning students together like other universities, we take a very involved approach to creating each floor and each condo-group and this matching technique puts more order to randomness, while being time efficient.*
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> *Many factors are used to create a balanced mixture of students on each floor (year of study, international mix, preferences, male/female balance and our unique personal knowledge of people). We balance all of these to create, what we hope is the best community, while also trying to match your preferences as much as possible.*
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> *Another cool thing... Unlike any other university, Admissions Counsellors at Quest made a first pass as creating room-mate pairs and condo groups based on how they know you, and the data from your applications. You are not just a number at Quest!*
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> *Finally we in Student Affairs work hard to use these complex preference matching criteria to try to find the best possible matches. Once the formula pops out good matches we use a whole bunch of good old human consideration to help finalize your placements. It's a combination of human intelligence, technology and people coming together to collaborate.*
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> *Pretty cool huh?!?*

Thanks to this one student, these 225 incoming students were matched to their roommates more effectively than in years past. And while this student will likely never take another math course, she has overcome her hatred of the subject, and has realized that mathematics is beautiful and meaningful, and is relevant to everything in this world. Just as importantly, this student will never be afraid of mathematics, ever again.

Since Quest is all about questions rather than answers, I leave with two questions that would form the basis for our discussion at the Canadian Mathematics Education Forum:

> *1) If you could design an introductory undergraduate mathematics course, completely from scratch, what would you teach and why? Would you opt for a broad survey course in mathematics, a traditional course such as Calculus or Linear Algebra, or something entirely different?*
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> *2) How should a student learn mathematics at the undergraduate level? In your opinion, is an intense focused engagement with the subject positive or negative? Does the Quest "block" format of having students spend their entire month learning mathematics hinder or enhance one's ability to retain the subject?*