Math Catcher Outreach Program

Veselin Jungić

Introduction

I have worked as a mathematician at universities for most of my adult life. Although teaching and research have formed the core of my professional activities, my experiences working with Indigenous students, academic partners, and friends have been among the most rewarding of my career.

As a mathematician who immigrated to Canada, I have taught and promoted mathematics among Indigenous learners since 1994 when I volunteered as a math tutor at Carnegie Community Centre,[1] Vancouver, British Columbia. In the mid-2000s, I was among those who started the Simon Fraser University[2] (SFU) Indigenous University Preparation Program[3] and in the late 2000s I volunteered at the Vancouver Aboriginal Centre.[4] After attending the First Nations Math Education Workshop[5] in Banff, Alberta, in 2009, I launched the Math Catcher Outreach Program.[6]

The program was inspired by the following two conclusions identified by Workshop participants as strategies for overcoming challenges in teaching mathematics to Indigenous youth:

- Teach mathematics in the cultural context of the students; and
- Teach basic skills and problem-solving early.

These two strategies resonated well with my own experience as a mathematics educator.

In my view, it is very difficult, if even possible, to find two people who have experienced mathematics in exactly the same way. I have had the privilege to teach mathematics to some extraordinarily talented young people who would instantly accept new concepts and understand them from the outset in a deeper and more substantial way than I, their teacher, could. For them, mathematics was their personal calling: the air that they breathed. But I also have worked with people with deep mathematical scars; with people successful in any way one could imagine, but who would turn their heads the other way if someone even mentioned the "m-word." Dealing with this wide range of attitudes towards mathematics, from ultimate devotion to undisguised fear, is a challenge that a teacher who teaches mathematics to the general student population faces daily.

In 1908, Arthur N. Talbot, an American civil engineer, wrote:

> I want to make a plea for the average student, the [student] whose analytical powers have to be encouraged and developed. The methods of presentation must be made elastic enough to include this great class of students, or we shall fail our duty as teachers. [MWWT1908]

A modern mathematics teacher, at any level of instruction, faces the same challenge: How to reach out to those students who, possibly at very young age, alienate themselves from mathematics? How to communicate to those students that learning and doing mathematics is an interesting, useful, and important experience that can lead to feelings of pride, happiness, and joy?

Hence the essence of the Math Catcher Outreach Program may be summarized as follows:

> Reach out to those students, Indigenous and non-Indigenous, whose mathematical interest

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[1] https://vancouver.ca/parks-recreation-culture/carnegie-community-centre.aspx

[2] https://www.sfu.ca/

[3] https://www.sfu.ca/fass/students/future/iupp/overview.html

[4] http://www.vafcs.org/

[5] https://www.birs.ca/events/2009/5-day-workshops/09w5078

[6] https://www.sfu.ca/mathcatcher.html

> and talents must be encouraged and developed by introducing mathematical concepts in the cultural context of the students and by teaching basic skills and problem-solving early.

From its very beginning, the program has had strong Indigenous components: witnessing storytelling by Elder Rena Sinclair of the Siksika Nation[7] was the moment of conception of the program; over the years my mentor and friend Elder Betty Wilson of the Tla'amin Nation[8] has been a major influence in the development of the program; before the pandemic, I regularly visited First Nation communities across British Columbia and Alberta; the program has organized events for Indigenous students; program volunteers have been mostly my former students from the SFU Indigenous University Preparation Program; the program has engaged Indigenous support/resource teachers from across BC; the program has created animated films in numerous First Nation languages; and we have coordinated volunteer tutoring activities between the Native Education College[9] in Vancouver, BC, and SFU.

At the same time, the Math Catcher Outreach Program is a mathematics program. For example, through its workshops, it exposes participants to an array of mathematical topics ranging from mental arithmetic, to learning about exponential growth through a well-known wheat and chessboard tale,[10] to exploring the properties of one-sided surfaces, to building George W. Hart's pencil model of a hexastix.[11]

This unity of serving as a mathematics initiative inspired and guided by members of the Indigenous community, is represented by the Math Catcher Outreach Program logo. The image in Figure 1 was created by Ms. Bethani L'Heuruex of the Cree Nation. It was Ms. L'Heureux and the author's take on an edge-colouring of the complete graph on 14 vertices by 23 colours that avoids both monochromatic and rainbow complete subgraphs on four vertices. The colouring was constructed by Tomas Kaiser, Daniel Král, and the author in [JKK2009].

Figure 1. The Math Catcher Outreach Program logo.

Aims

In 2011, the primary objective of the program was stated as:

> To promote mathematics among elementary and high school students, as well as members of Indigenous communities, both in urban settings and on reserves. This is to be done in a way that Indigenous children see themselves and their culture connected with mathematics. [JM2011]

Over the years, this objective has broadened.

Probably the most important reason for this change was the fact that coordinating the Math Catcher Outreach Program has been a transformational learning experience for me.

Through the Math Catcher Outreach Program, I have had the privilege to interact with hundreds of Indigenous students and their parents, elders, teachers, and the community members, both in urban and rural settings. Since my volunteering days in East Vancouver, it has always been clear to me that there is an abundance of talent and interest in mathematics among Indigenous learners [J2018]. It has also become evident to me that there is a profound mathematical presence integrated in various Indigenous traditions and practices [J2019]. This presence ranges from the weaving patterns in cedar root and birch bark baskets to canoe designs and the ways of sea and land navigation, to the strategies employed in the salmon harvest, to the ways of optimizing and managing available resources. It is almost impossible to find an Indigenous piece of art, ancient or modern, that does not contain clearly recognizable geometrical objects, patterns, and various, sometimes quite complex, symmetries [TS2011].

Conversations with my Indigenous mentors, academic collaborators, and friends led me to learn more about the concept of ethnomathematics as it was introduced by Ubiratan D'Ambrosio, a Brazilian mathematics educator [D1985]; Allan Bishop, an Australian mathematics educator, who views mathematics as a form of cultural knowledge [B1988]; and the notion of two-eyed seeing as introduced by Elder Albert Marshall of the Mi'kmaw Nation [BMMI2015]. Consequently, my perception of the purpose of the Math Catcher Outreach Program evolved. Possibly the most significant change was the realization that Math Catcher activities were an opportunity for all involved to

[7] https://siksikanation.com/
[8] https://www.tlaaminnation.com/
[9] https://necvancouver.ca/
[10] https://proofwiki.org/wiki/Wheat_and_Chessboard_Problem
[11] https://www.georgehart.com/sculpture/pencils.html

learn from each other. In particular, this meant creating situations where participants, including those very young, could learn or discover new mathematics through a guided demonstration of their own mathematical thinking and knowledge. In [JY2020] I described what First and Second Grade students taught me about the dynamic between the concepts of cardinal and ordinal numbers.

An unavoidable part of this process was learning about and witnessing some of the tragic consequences of colonization in Canada and the role that mathematics played in it [AJ2016]. In this light, the following question became very personal: What can educators do to help repair the damage caused by years of benign neglect and intentional harm and promote mathematics and other STEM subjects among Indigenous youth so that they can launch careers that will benefit their communities?

Another important reason for broadening the program's aims was the change in the political climate in Canada after the release of the Truth and Reconciliation Commission's final report in 2015. The final report contained several education-related calls for action [TRCC2015]. As a response, educational institutions across Canada, with the involvement of their Indigenous students, staff, and faculty, and in a collaboration with the local First Nations, created their own reconciliation related initiatives.[12]

The lack of Indigenous-related and freely and easily accessible mathematical resources and the fact that the Math Catcher Outreach Program was inspired and guided by members of the Indigenous community made the program more visible among Canadian mathematics educators. This meant an increase in the demand for Math Catcher workshops and resources, and for new initiatives and activities, from the non-Indigenous teaching and academic community, particularly at the elementary school level.

Meanwhile, in the spirit of the Truth and Reconciliation Commission's final report, voices from Indigenous communities were taking the central stage when creating and implementing Indigenous related educational initiatives and programs.

For the sake of transparency and my personal intent to promote reconciliation, I made it clear that the Math Catcher Outreach Program, while involving and serving Indigenous individuals and communities did not begin as and was not an Indigenous-led program. My sincere hope is that Indigenous educators and other leaders draw from the program in the future, as we have drawn from their wisdom and experience.

Even in the time of the pandemic, this transparency did not decrease the interest in the Math Catcher Outreach Program at the local, Canadian, and international levels.

For example, Dr. Heather Bleecker, a math faculty member at Salish Kootenai College, Pablo, Montana, together with her two undergraduate students used Math Catcher Outreach Program-created resources as part of their presentation at the 2021 National Council of Teachers of Mathematics conference. The title of the presentation was "Culturally Connecting Geometry through Storytelling."

Visiting hundreds of elementary and high school classrooms across BC over the last several years has made me even more aware that students and teachers of mathematics need an ally from outside who would provide students with even a brief, positive experience with mathematics.

This positive experience, in my view, includes connecting mathematical concepts to everyday life, withstanding the complexity of the underlying mathematics. The Math Catcher Outreach Program aims to link mathematics to the "real world" through exercises, stories, and other examples as expanded on in the following section. I have no doubt that by forging a connection between mathematical concepts and the world students live in, the subject can become less intimidating and even attractive.

Another obstacle that promoters of mathematics must overcome is to make the subject interesting for an audience accustomed to modern instant gratification as conditioned by social media. Therefore, as a way of creating a positive experience with mathematics, through intriguing activities, by using the elements of pop culture, and even entertaining students, the Math Catcher Outreach Program intends to motivate their ongoing study.

In summary, the main goal of the Math Catcher Outreach Program is to encourage young Indigenous and non-Indigenous students to discover the joy and appeal of mathematics at a critical age.

My hope is that the Math Catcher Program's events and resources will help young learners better understand the presence and importance of mathematics in everyday life and inspire them to consider mathematics as a field of study and vocation in the future.

Methods

The Math Catcher Outreach Program is made up of a series of initiatives, all designed with primary and secondary school audiences in mind. The program can be divided into several components: the Small Number stories and the accompanied videos in multiple languages; classroom resources based on the Small Number stories; in-class demonstrations; role models; annual workshops and academic fairs; conference presentations; professional development workshops for teachers; summer camps; and volunteer initiatives.

The Small Number stories, co-written by Dr. Mark MacLean from the University of British Columbia and the author [JM2021], continue to comprise the core element of the Math Catcher Outreach Program. Small Number is a

[12] *See for example,* https://www.sfu.ca/aboriginalpeoples/sfu-reconciliation.html.

young boy who has an impressive aptitude for mathematics—and a proclivity for getting into trouble.

The name of our hero was inspired by two mathematical laws and experiences that I had as an instructor, a promoter of mathematics, and a volunteer. The result of these experiences—an impression that early math potential often is not matched with an optimal outcome—might be described by the Law of Small Numbers as it was stated in [GRS1990]:

> Patterns discovered for small k disappear for k sufficiently large to make calculations difficult.

Another experience—some of the best students in my mathematics classes come from other programs ranging from music to economics to engineering and computing science—would probably be better described by the Strong Law of Small Numbers [G1988]:

> There aren't enough small numbers to meet the many demands made of them.[13]

In the numerous stories, Small Number has his mathematical adventures in various physical settings: some in urban areas and others in rural settings. In each story, Small Number encounters a problem that requires mathematics to solve. Through interactions with friends and loved ones, Small Number learns more about the different aspects of the problem and the end of each story poses a question to the audience.

The purpose of the stories is to demonstrate the program's main aims: that mathematics is present and applicable in real life; that young people, like Small Number, in their everyday activities encounter and require a knowledge of mathematics; that mathematics can be interesting; and that mathematics can be used to solve problems (for example, as discussions can conclude, in a career).

Alana Underwood, an elementary school teacher from Coquitlam, BC, commented:

> I feel that encouraging students to value the context of the story in Small Number films makes the ensuing mathematics activity more relatable to students and proves that learning can be embedded in story. [U2019]

The stories and videos are playful and promote kin and friendship connections. Just as importantly, the stories are used to reflect some elements of Indigenous tradition, knowledge, and culture. Of course, Indigenous culture is not a singular, cohesive set of beliefs and practices, but a myriad of traditional and modern values and rituals. Therefore, Small Number's adventures take place in various physical contexts in different communities, and yet the character of the clever, playful protagonist remains the same.

The stories have been translated from English into eleven Indigenous languages as well as French and Spanish. Some of those Indigenous languages are endangered and an important—if initially unintended—contribution of the Math Catcher Outreach Program has been to contribute to the digital recording and preservation of some Indigenous languages.

Since its inception the Math Catcher Outreach Program has visited hundreds of classrooms in British Columbia and other parts of Western Canada.

An important feature of the popular school visits is the interactive component between Math Catcher volunteers and students. The sessions begin with a short presentation by the author, who tells students his personal story through a sequence of mathematical riddles and explains the importance of mathematics in his life. Perhaps even more importantly, STEM undergraduate and graduate students who serve as volunteers also share their experiences, which makes studying mathematics more relatable to young people as they can see a young person not too many years older than themselves succeeding in the subject.

What is even more powerful is that the program has succeeded in attracting STEM students from Indigenous backgrounds to serve as volunteers [A2018]. The shared experience of these young people has had a profound effect on many audiences as it provides demonstrable proof that they can succeed in mathematics if they choose to pursue it. These young volunteers, among other themes, discuss the careers they have chosen and continue to pursue. By involving undergraduate and graduate students in the process, Math Catcher organizers believe that they have achieved their aim of planting the seed of possibility in the minds of their young audience members.

In addition to highlighting role models, the interactive class sessions also feature the construction of geometric objects that provide a tangible example of mathematics at work. For example, the tensegrity exercises created by Alejandro Erickson,[14] a volunteer in the program, have proven immensely popular among young students, as demonstrated by numerous letters from teachers and even students themselves. The tensegrity exercise allows students to see physical mathematics that they can create and manipulate. Although the product is a mathematical model,

[13] *The Strong Law of Small Numbers was stated by Richard Guy, a legendary British and Canadian mathematician, 1916–2020. Professor Guy was a regular participant at the First Nations Math Education Workshops that were held in Banff, AB, in the late 2000s and the early 2010s. It should be mentioned that he was not there just as an observer in something that had caught his eye in passing as being possibly interesting, but as an active and quite spirited participant. Another workshop participant reminded me recently how, on one occasion, after Professor Guy finished presenting something mathematically interesting, one of the elders said, with a smile on his face, "Richard, I have no idea what you just did, but when you do it, it makes me want to do it too!"*

[14] https://www.facebook.com/geoburst/?comment_id=Y29tbWVudDo0MjkwMDU3MDM4MDczMDRfNDI5MDExMjM3MTQwMDg0

it also serves as a toy and a souvenir from the session that students can take home.

To support teachers and students in the exploration of the mathematical concepts contained in the Small Number stories, we are creating a series of classroom resources based on each story [J2021]. Each resource includes the following: mathematical concepts contained in the story; mathematical vocabulary used in the story; cultural components in the story; possible answers to the open-ended question at the end of the story; and mathematics in- and out-of-classroom activities based on the story.

For several years, the Math Catcher Outreach Program hosted one-day workshops on the SFU campus for Indigenous high school students. These events involved numerous activities with a mathematics or other STEM themes. These well-attended sessions allowed the program to feature other components that are present at school visits—the Small Number videos, hands-on activities, and role models—while also allowing students to become comfortable in a university setting. Rather than tolerating the misconception that universities are distant, unreachable institutions for someone else, the workshops allowed Indigenous students to visit and familiarize themselves with an institution that they might one day attend if they choose to follow the path presented to them.

Between 2014–18, the Math Catcher Program organized the Annual Simon Fraser University Academic Summer Camp for Indigenous High School Students [JT2020]. The main purpose of the camp was to strengthen academic engagement and cultural awareness among First Nations, Metis, and Inuit (FNMI) students who attended, regardless of their high school grades. This was an important decision as it manifested our commitment to meeting youth wherever they were in their learning journeys.

The camp operated as a day-camp,[15] from 9am–4pm, Monday–Friday, over four weeks in July. The camp participants, a group of about two dozen self-identified FNMI high school students, attended math and English classes and participated in workshops on topics including chemistry, statistics, physics, biology, earth science, engineering, and computing science. Camp participants were also involved in numerous activities relating to Indigenous cultures and traditions. By the end of the camp, each camp participant had engaged in approximately 30 hours of mathematics and 30 hours of English classes, 24 hours of STEM experience, 10 hours of cultural activities, 8 hours of sport activities, and 8 hours of other activities including career planning, listening to guest speakers, attending public speaking workshops, and team-building activities.

Possibly the proudest achievement for the camp organizers and staff was that, although the group of participants was very diverse, all students accepted to the camp over five years completed the program. It was particularly rewarding to witness how quickly camp participants were able to form a tightly connected group of committed learners.

The program's latest initiative, the Math Catcher Festival,[16] was envisioned as a celebration of students' imagination and creativity and their knowledge of mathematics and Indigenous cultures and traditions and designed to reflect the values of the overall Math Catchers Outreach Program. In the call for submissions, teachers of Grades 4–5 students from BC and other parts of Canada are invited to have their students create Small Number stories and present them in the media of their choice.

The festival includes two parts: the first consists of several weeks of students' work on their projects and the second features the Festival Day when the student-created Small Number stories are showcased with several additional activities, such as guest speakers and presentations of various Small Number films.

For the author, as a teacher of mathematics, probably the most valuable learning experience from reading and watching students' submissions to the 2020 and 2021 Math Catcher Festival has been the affirmation that even young students[17] can talk about various mathematical concepts within the plot of their own story. Beyond the expected, the grade-appropriate range of mathematical topics, such as using positive integers and positive rational numbers and using arithmetic operations, the mathematics presented in students' stories included:

- Problems or solution strategies that used arithmetic or geometric progressions.
- The intuitive side of the idea of colouring as used in Ramsey theory: A set partition into several cells of the same or different cardinalities; different colours represent different partition cells and therefore emphasize the fact that the cells are mutually disjoint.
- Applications of the pigeonhole principle.
- Game theory: A fair division by an algorithm or by chance.

As an example, here is a story by a 10-year-old student from a rural school in BC:

> Once upon a time there was a five-year old boy named Small Number that would get in a lot of trouble. Today, he got to choose who received

[15] *The "day camp" format restricted the targeted audience to the Indigenous youth from the Greater Vancouver area. There are examples of residential summer programs for Indigenous students that serve some less densely populated areas. One example is the Montana American Indians in Math and Science (MT AIMS) Summer Camp at the University of Montana,* https://www.mthightech.org/news/mapping-the-course-for-montana-native-american-students-in-stem.

[16] https://www.sfu.ca/mathcatcher/math-catcher-festival.html

[17] *In British Columbia, students enrolled in Grades 4 and 5 are usually 9–10 year-old children.*

which cake. There were five people in his family altogether. There was strawberry, chocolate, peach, vanilla, and cookies and cream. Unfortunately, his favourite cake was strawberry and that was his sister's favourite too. His sister's name was Perfect Number.

Small Number did not know what to do. Should he give away his favourite flavoured cake to his sister? His tiny little cousins tried to help him by letting him know their choice: "Can we have strawberry?" His mother, quickly, also asked him, "Can you let me have strawberry?"

Small Number's solution was unusual, everyone would receive a fifth of each cake instead. When he told his solution to the family they said in unison, "That is a great idea Small Number."[18]

I briefly mention three other Math Catcher Program initiatives: an eleven-year old tutor volunteering program between the Native Education College in Vancouver, BC, and SFU; a steady stream of workshops and conference presentations for teachers, academics, and general public at the local, provincial, national, and international levels; and a collaboration with the Tla'amin Nation, the Pacific Institute for Mathematical Sciences,[19] and Cybera,[20] that resulted in mathematical models of several traditional Tla'amin practices.[21]

Conclusion

The Math Catcher Outreach Program has been part of the Canadian educational environment since 2011. Through more than 800 classroom visits, workshops, and journal, magazine, and newspapers articles, as well as more than a dozen Small Number stories, the program has reached tens of thousands of students, educators, and members of the public from across British Columbia, Canada, and around the world.

During these years, the main goal of the program has changed from focusing on Indigenous students to becoming a source of the encouragement to all students to explore their mathematical talents and interests.

One of the common questions that I encounter throughout the mathematics outreach side of my career is: "How do you measure the success of what you do?"

What too many of my undoubtedly well-meaning colleagues, both on the instruction and administration sides, mean by "success" in this context is that the participation in the Math Catcher Outreach Program activities would primarily be "a social marker of success that leads to upward career advancement and higher socio-economic status." [P2009]

The reality of the wide range of attitudes towards mathematics is deeply rooted in a maze of issues that may be personal, institutional, socioeconomic, political, and historical. Hence, it would be unrealistic to expect that by attending a one-day or a one-month-long event each participant would find the answers to all of their learning and other educational needs.

Consequently, in my view, in addition to encouraging students to fully explore their mathematical talents and interests, the success of an outreach program for the general audience includes that moment of excitement and joy that doing mathematics brings to the life of an individual participant.

Yes, the Math Catcher Outreach Program's main goal is to motivate and help students to move "upward," but a message like the one below justifies all of the efforts that volunteers, and supporters have put into the Math Catcher Outreach Program over the many years:

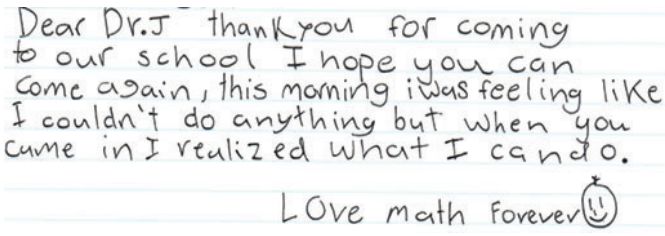

Figure 2.

[18] http://www.sfu.ca/~vjungic/MCFestival/chap_MCF_11.html

[19] https://www.pims.math.ca/

[20] https://www.cybera.ca/

[21] *Very recently the American Museum of Natural History (*https://www.amnh.org/*) asked for permission to use some of the resources created in this project.*

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Credits

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