Windows into Elementary Mathematics: Alternate public images of mathematics and mathematicians

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ABSTRACT

Research on students' (and teachers') images of mathematics and mathematicians reveals a number of stereotypical images, most of which are negative. In this paper we present an overview of some these images and stereotypes and consider the questions: (1) how might the image of mathematics and mathematicians be a problem in mathematics education, and (2) what can be done to remedy the situation? Also, we consider an outreach project called *Windows into Elementary Mathematics*. In this project mathematicians are interviewed about their perspectives on elementary mathematics topics and their interviews are videotaped and are posted online, along with supporting images and interactive content. In this context we consider the questions: (3) what is the Windows project about, and (4) how might it offer an alternate (and perhaps better) image of mathematics and mathematicians? Lastly, we share an example where activities from the project were used in a math-for-teachers course.

Keywords: Mathematics Education. Image of Mathematicians. Elementary Mathematics. Virtual Learning Objects.

Janelas para Matemática Elementar: imagens públicas alternativas de matemática e matemáticos

RESUMO

Pesquisas sobre as imagens de estudantes e professores sobre matemática e sobre matemáticos revelam uma série de imagens estereotipadas, das quais muitas são negativas. Neste artigo, apresentamos uma visão geral de algumas dessas imagens e estereótipos e consideramos as seguintes questões: (1) Como a imagem da matemática e dos matemáticos pode ser um problema em educação matemática, e (2) o que pode ser feito para melhorar a situação? Além disso, consideramos um projeto de extensão chamado de "Janelas para Matemática Elementar". Neste projeto, matemáticos são entrevistados sobre suas perspectivas sobre tópicos de matemática elementar e suas entrevistas são filmadas e publicadas on-line, junto com figuras de apoio e conteúdos interativos. Neste contexto, consideramos as seguintes perguntas: (3) sobre o que se trata o projeto "Janelas", e (4) como ele poderia oferecer uma alternativa (talvez melhor) sobre a imagem da matemática e de matemáticos? Finalmente, compartilhamos um exemplo, o qual as atividades do projeto foram usadas em um curso de matemática-para-professores.

Palavras-chave: Educação Matemática. Imagem de Matemáticos. Matemática Elementar. Objetos Virtuais de Aprendizagem.

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IMAGES OF MATHEMATICS AND MATHEMATICIANS

Many researchers have discussed the negative public image of mathematics and mathematicians (FRANK, 1990; SPANGLER, 1992; FURINGHETTI, 1993; ERNEST, 1995; ROCK; SHAW, 2000; PICKER; BERRY, 2000; LIM; ERNEST, 1999; LIM, 1999; 2002; RENSAA, 2006). But why might the image of mathematics and mathematicians be a problem in mathematics education?

Ernest (1995, p.449) described the "widespread public image of mathematics as cold, abstract, and inhuman, and relates it to absolutist philosophies of mathematics". In this context, Lim (1999, p.2) pointed out that

> The term 'image of mathematics' is conceptualised as a mental representation or view of mathematics, presumably constructed as a result of social experiences, mediated through interactions at school, or the influence of parents, teachers, peers or mass media. This is also understood broadly to include all visual and verbal representations, metaphorical images and associations, beliefs, attitudes and feelings related to mathematics and mathematics learning experiences.

Furinghetti (1993) focused on the images of mathematics outside the community of mathematicians. Initially, Furinghetti (1993, p.33) argued:

> The image of mathematics among professional mathematics is tortuous and controversial; it should not surprise us, therefore, that for mathematics teachers, deciding what image to transmit to their pupils is a source of doubt. Linked to the discussion on the nature of mathematics is the discussion about the figure of mathematician and about what creativity means in mathematics.

Based on this initial statement, Furinghetti (1993) analyzed several books and movies to identify the most common stereotypes of mathematics in the media. In other word, she focused images of mathematics for the non-mathematicians. Her findings in terms of *stereotypes from books* were: "Mathematics as an activity of perfect reasoning and synonym for truth and certainty" (FURINGHETTI, p.34); "Mathematics as one of the keys to understand physical reality" (FURINGHETTI, p.34); "There is a correct teaching approach in the learning of mathematics (FURINGHETTI, p.35). Mathematics school experience is fundamental for the formation and development of the individual. Teachers are seemed as synonymous of coldness. She identified similar *stereotypes from cinema*: "Mathematics as synonym of correct reasoning" (FURINGHETTI, p.36). Mathematics is seen as synonym of purity. There is an "incompatibility between femininity and mathematics" (FURINGHETTI, p.36). It is common see "bad schools relationships with mathematics" (FURINGHETTI, p.36).

Renssa (2006) interviewed people in an airport terminal focusing on their image of mathematicians. She created a survey to ask people how they imagine a mathematicians looks. In her conclusions, she pointed out that many people (non-mathematicians) see

> [...] mathematician as a man working in his office or teaching his subject, but else not doing things that can be used in the society. It is tempting to predict that to some people mathematicians are understood to work with another type of mathematics – "research mathematics" – than the mathematics that the public has learned at school. This type of mathematics may look boring and not understandable and therefore cause the rather negative image of the profession of being a mathematician. (RENSSA, 2006)

Rock and Shaw (2000) became curious after reviewing findings in studies about children's images of scientists. They asked 'what do children think about mathematicians?' To highlight this query, they focused on three questions: "(1) What do mathematicians do? (2) What types of problems mathematicians solve? (3) What tools do mathematicians use? (ROCK; SHAW, 2000, p.551). Rock and Shaw (2000) used these questions to create an online voluntary survey for students and several grades (from kindergarten to grade-8). Also, they invited children to mail drawings of mathematicians at work. They received 215 responses from children. Three of the themes in the results of Rock and Shaw's work are described below:

Mathematicians at work: the most often kindergartners' responses were: 'Mathematicians do calendar, teach numbers work with numbers, and make numbers'. One "negative" image was: 'Mathematicians are monsters, and they are about to eat these people'. Most students from first to eighth grades provided more general responses as 'Mathematicians are good in mathematics' or 'Math is what mathematicians do; no more, no less'. Some students presented images as: 'Mathematicians do math all day. They work hard. They are smart and diligent. They do problems. They are great. They are people engaged in activities as cutting the grass, painting pictures, and living in attractive homes'. Most responses and drawings expressed image of the classroom as the main place of mathematicians' work.

Problems mathematicians solve: The typical students' responses were: 'Mathematicians solve hard problems other people don't know'. 'They do hard problems'. 'They solve hard notations as 1,000,000 x 1,000,000 and 184 + 674'. 'They solve new problems'. 'They do things like going into outer space'. 'They work with money'. 'They solve very difficult problems' 'that no more else solve', 'problems that take a long time'. 'Mathematicians are needed in such endeavors as finding how long it would take to get to the sun or determining the distance from the moon to one of Jupiter's moons'.

Mathematicians' tools: Kindergartners and first grade students answered: 'pencils, paper, chalkboards, calendars and number cards'. In other grades, students said ‘computers, calculators, paper, pencil, erasers, rulers, geometric shapes, blocks, fingers, hands, brain, and mind’. Rock and Shaw (2000) argued that the frequency of responses involving the use of the brain as an important tool of mathematicians was a surprising finding.

Picker and Berry (2001, p.202) argued that finding out more about students’ images of mathematics and mathematicians can help teachers “understand their attitudes toward, misconceptions about, and opinions of the subject”. And, “one way to discover these attitudes is to ask your students to create a drawing of a mathematician”. Picker and Berry (2000, p.65), based on 476 students’ drawings from an international survey proposed in five countries, reported that “with small cultural differences certain stereotypical images of mathematicians are common to pupils” and “these images indicate that for pupils of this age [ages 12-13] mathematicians and the work they do are, for all practical purposes, invisible”.

Picker and Berry (2000, p.74) proposed seven themes to identify similarities in the drawings made by students in different countries: (1) *Mathematics as coercion*: students “drew mathematicians as teachers who use intimidation, violence, or threats of violence to make their pupils learn material. This was a completely unexpected theme that emerged from the drawings”; (2) *The foolish mathematicians*: “mathematicians were depicted as lacking common sense, fashion sense, or computational abilities”; (3) *The overwrought mathematician*: “mathematicians were depicted as looking wild and being overstrained”; (4) *Mathematicians who can’t teach*: “a classroom is drawn which the mathematician cannot control, or in which he doesn’t know the material”; (5) *Disparagement of mathematicians*: mathematicians “as being too clever or in some other way contemptible”; (6) *The Einstein effect*: drawings with a reference to Albert Einstein. Usually, those images were influenced by media, including books and cartoons; (7) *Mathematicians with special powers*: it includes wizardry and math potions. “Something extraordinary is necessary in order to do mathematics”.

In their conclusion, Picker and Berry (2000, p.88) point out

> The largest finding of our study is that for pupil of this age [12-13], mathematicians are essentially invisible, with the result that pupils appear to rely on stereotypical images from media to provide image of mathematicians when asked. Pupils believe that mathematicians do applications similar to those they have seen in their own mathematics classes (…). They also believe that a mathematician’s work involves accounting, doing taxes and bills, and baking; work which they contend includes doing hard sums or hard problems; yet pupils can supply no specifics about what such problems entail (…). In providing the images on our survey tool, we could not have anticipated how much pupils would provide a window onto their experiences in their mathematical classes. We believe that drawings created by the pupils contain valuable insights with significant implications for teachers, their training and their practise.

Some issues on students' images of mathematics and mathematicians involve discussions about gender. Rock and Shaw (2000) and Picker and Berry (2000) highlighted perspectives about male and female students' images and the gender of the mathematician drawn (which typically was male).

CHANGING IMAGES OF MATHEMATICS AND MATHEMATICIANS

Our literature review provides us the following perspectives: most the students' and adults' images of mathematics and mathematicians are negative. They recognize mathematics as cognitively important, but they see mathematics as a cold science and reduce the mathematicians' work to traditional classroom mathematics. Also, they associate 'do math' with traditional tools of classrooms and with men's work. What can be done about this negative image?

Frank (1990, p.12) agued that one "way to change beliefs about mathematics may be to develop students' awareness of their own, and others', mathematical beliefs". However, Frank's (1990) principal suggestion for changing mathematical beliefs deals with changing the mathematical curriculum. She pointed out students who had not experienced problem-solving approaches recognize mathematics as memorization of rules to apply in problems while students who worked with heuristics did not hold this myth.

> Changing the mathematics curriculum from one that focuses on drill and practice of number facts and computational algorithms to one that emphasizes problem solving, estimation, and conceptual understanding may result in a change in students' beliefs about mathematics. (FRANCK'S, 1990, p.12)

Frank and Shaw (2000) indicated that one way to change students' images of mathematics is by making connections between mathematics and children's everyday life. Also, they suggested that students need to learn about history of mathematics. Picker and Berry (2001) suggested that teachers might invite professional mathematicians to talk about their job to students in mathematics classrooms, focusing on disrupting negative students' images of mathematicians. Conducting research in libraries and on the internet is also indicated.

In terms of gender issues, Rensaa (2006) emphasized of role of media in supporting the view of mathematics as an activity for males. Some research has been done focusing on the role of women in the history of mathematics, emphasizing big math ideas created by female mathematicians and their brilliant academic carriers (CAVALARI, 2007). And some work has been done in the media to place females in the roles of scientists and mathematicians. The actress and mathematician Danica Mckellar, famous for performing the role of *Winnie Cooper* in the TV show *Wonder Years*, has written math books for girls

(MCKELLAR, 2008). Mckellar has used her media influence to provide the image that “math is for girls too” and “math can be fashionable”.

Mckellar’s idea of mathematicians of bringing mathematics to a school audience is interesting as it can potentially affect students’ images of both mathematicians and mathematics. This approach of bringing both mathematicians and mathematics to a school audience (and beyond) is the goal of the Windows into Elementary Mathematics project of the Fields Institute.

WINDOWS INTO ELEMENTARY MATHEMATICS

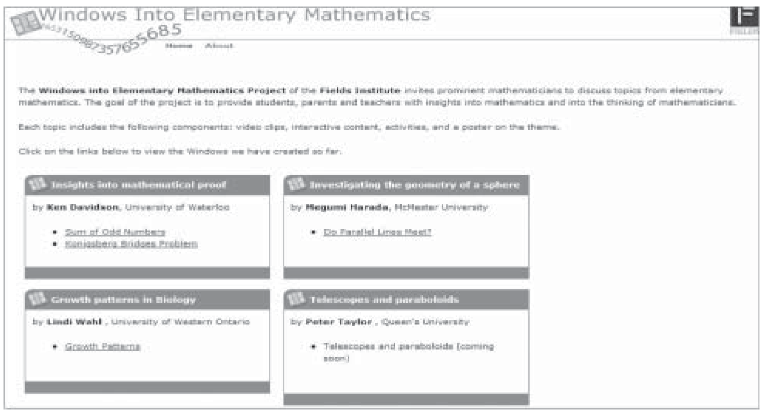

FIGURE 1 – Home page of the project website.

Windows into Elementary Mathematics[1] (GADANIDIS, 2009a) is a project developed by the first author with funding supported by the Fields Institute (FIELDS INSTITUTE, 2009)[2]. In this project mathematicians are interviewed about their perspectives on elementary mathematics topics and the interviews are videotaped and posted online, along with supporting images and interactive content. The home page of the project website is shown in Figure 1. Also, posters about the mathematics ideas are available as pdf files (see Figure 2).

1 Ver http://www.fields.utoronto.ca/mathwindows/
2 Ver http://www.fields.utoronto.ca/

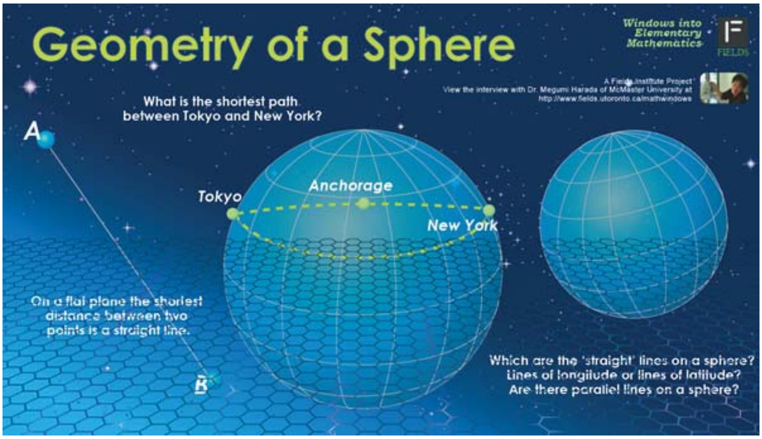

FIGURE 2 – Poster.

Below we discuss the four mathematical topics addressed by the mathematicians in this project.

(1) *Insights into mathematical proof:* In this theme, Dr. Ken Davidson (University of Waterloo) talks about two math ideas (see Figure 3). (a) He presents an investigation of series of odd numbers, using manipulative blocks to identify patterns, generalize these patterns and conjecture that $1 + 3 + 5 + 7 + \ldots + (2n - 1) = n^2$. Dr. Davidson uses induction proof to provide this result, but he demonstrates the important role of manupulatives in visual "proofs". Also, he proposes a similar investigation involving the series of even numbers. (b) Dr. Davidson presents an investigation on the *Konigberg Bridges* problem and discusses issues involving the *status* of mathematical proofs.

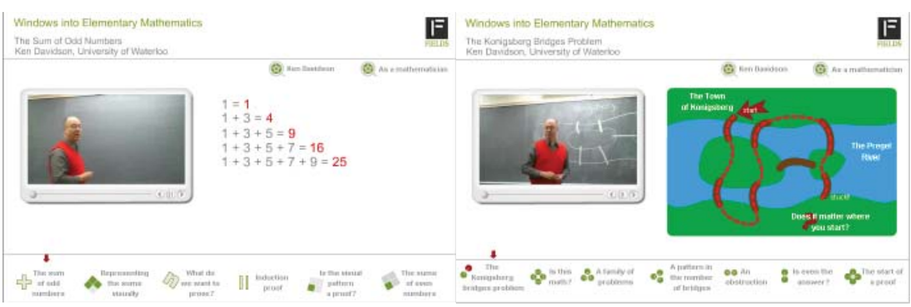

FIGURE 3 – Dr. Ken Davidson.

(2) *Investigating the geometry of a sphere:* **This theme is presented by Dr. Megumi Harada,** (McMaster University) (see Figure 4). Dr. Harada uses and inflatable globe and string to explore "What is the shortest path on the surface of a sphere?" and "Are there parallel lines on a sphere?" This theme disrupts what it means for lines to be straight or

parallel, as spherical geometry is not typically taught in school, even though we live our lives on a sphere (or an approximate sphere).

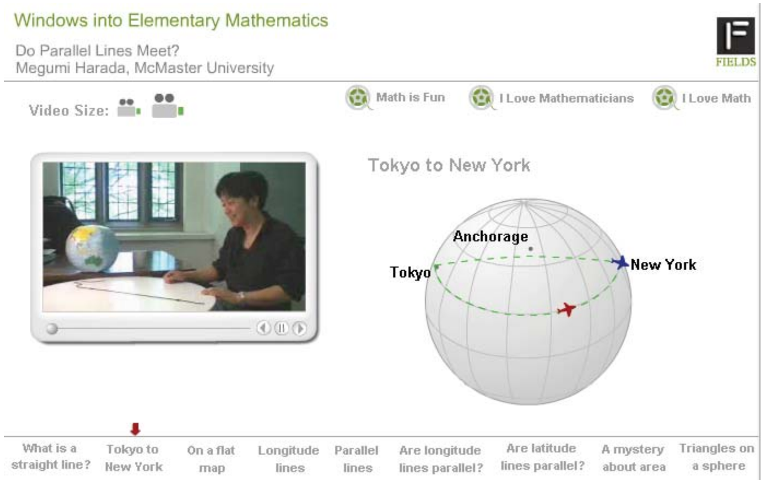

FIGURE 4 – Dr. Megumi Harada.

(3) *Growth patterns in Biology:* This theme is presented by Dr. Lindi Wahl (University of Western Ontario) (see Figure 5). Dr. Wahl works in the field of mathematical biology. In explaining how bacteria grow, she uses concrete materials to model two different growth patterns, one that is linear and one that is not. In this context, she talks about exponential growth.

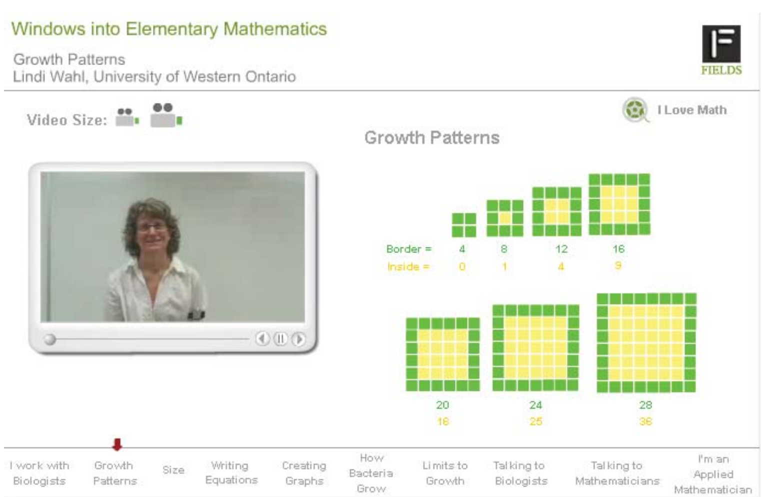

FIGURE 5 – Dr. Lindi Wahl.

(4) *Telescopes and paraboloids:* **This theme is presented** by Dr. **Peter Taylor (**Queen's University). Dr. Taylor introduces the interesting phenomenon that (a) parabolic mirrors are used in telescopes and (b) a rotating liquid naturally forms a parabolic surface. He then explains how a rotating bath of mercury is used to create large (and relatively inexpensive) telescopes. Dr. Taylor also discusses the mathematics involved.

ALTERNATE PUBLIC IMAGES OF MATHEMATICS AND MATHEMATICIANS

What are the images of mathematics and mathematicians supported by the *Windows into Elementary Mathematics* project? Is this project providing an alternate public image as compared to the public image of mathematics and mathematicians found in our literature review? We will address these questions by organizing our discussion in three categories: (1) the design of mathematical problems discussed by the mathematicians; (2) the mathematicians' view of mathematics; and (3) the tools involved in their mathematical thinking.

(1) *The design of mathematical problems*: The problems chosen by the mathematicians were complex and could not be answered with a simple statement or a simple procedure. The mathematicians also addressed the problems from multiple perspectives (using diagrams, manipulatives, verbal descriptions and mathematical symbols and expressions) and did so in an in-depth fashion, giving a sense of the complexity of mathematical ideas. They also posed other, similar problems, thus extending the problems in new directions. The image one gets of mathematics problems is that they involve exploration and conjecture. The problem posed by Dr Harada about spherical geometry also introduced possible uncertainties about mathematics knowledge by offering a much more complex understanding of what it means for lines to be straight or parallel. We live our lives on a sphere yet we tend to treat its surface as a flat plane. These mathematical problems stand in contrast to some of the stereotypical view of mathematics, where problems are seen as being solved using complex computations and or using set procedures. It is also interesting that most of the problems posed by the mathematicians had connections to real life, like the Earth, growth of bacteria, and the design of telescopes.

(2) *The mathematicians' view of mathematics.* The mathematicians interviewed for the project talk about their desire to understand and generalize, about the power and beauty of mathematics, and about the characteristics of mathematicians.

Dr. Davidson notes that when he went to school "the focus was always on getting the answer, but as a mathematician that's not my major focus." Rather, the goal is

> understanding why things are true, what's the general pattern, how can you solve a whole class of problems. You start with one problem and see how you have a whole family of problems of the same kind, how we can analyze a whole class so that we're not solving one problem but we're solving infinitely many problems at the same time.

Dr. Taylor explains that when he was in high school he was attracted by the power of mathematics to solve problems and to create a sense of certainty. However, his experience as a mathematician led him to be drawn more to the beauty of mathematics. He also suggests that mathematical beauty and mathematical power are linked because of their common reliance on mathematical structure.

> Now I chose the problems I do based on beauty. Beauty has a lot to do with structure. And power has a lot to do with structure. So it's really the structure of the universe that is amazing. The more beautiful something is, the more true it's likely to be.

Dr. Harada also is drawn to the beauty of mathematics. However, she explains that she is also drawn to mathematicians. She states "that there are two things that pretty much equally motivate why I come back to work everyday."

> Half of it is just the fact that I think math is beautiful, especially the geometry that I do. It's very intuitive, about shapes, and it's something that you can doodle on a piece of paper … as opposed to cranking out a lot of equations.

Second,

> I love mathematicians. When I was in university I studied a lot of things. I studied literature, I studied anthropology, I studied linguistics, I studied philosophy, it wasn't until my fourth year of university that I decided to pursue math. So I was doing a lot of other things before that, in fact I was an East Asian Studies major before I was a math major. I knew a whole lot of people as a young student and I can say that without any doubt that the math students were the most fun to be around, and I think it's because, as a group, mathematicians love what they do more than many, many other groups of people I know. … Mathematicians are a group of people who love math more than they love themselves. Somehow math is this huge, beautiful world that we're just a part of, were just playing in it, swimming in it, and sometimes we find wonderful jewels embedded in it. Somehow the world of math is bigger than us. Somehow there's a sense of humility that mathematicians share that really keeps us a tight knit community, a supportive community I'd like to think, and makes it really, rally fun to work with and talk with and explore with other people who share that same passion.

The mathematicians' expressed views of mathematics stand in contrast to the stereotypical view of mathematics as answer-focused, cold, impersonal and solitary activity. The mathematicians relate mathematics as a search for pattern and understanding, as a discipline full of beauty, and as an activity that often involves collaboration.

(3) *The tools involved in mathematical thinking.* In talking about the elementary mathematics that they chose to discuss, the mathematicians used a variety of tools: manipulatives, diagrams, doodles on a piece of paper, analogies and models, personal stories, and physical demonstrations. This is quite different from the typical public view of mathematicians working with numbers or simply solving problems in their head. In describing their work as mathematicians, they also brought to attention various other tools. Dr. Wahl discussed the use of data and graphs, and also the power of equations to capture and communicate patterns.

> Often I work with biologists … and I try to capture what is going on in mathematical language, so I might be able to write an equation if I'm lucky for what is going on or what they think is going on. … Instead of looking at just a graph of the data that they've measured or all the numbers we can have a simple equation and they can take that and it's much easier to test what might happen in the future by looking at that equation or you might test what might happen if things were different. And you can also explain to other people what happened in your experiments rather than showing them all the data you can show them the very concise, beautiful mathematical expression: what the key features are for this experiment.

Dr. Harada also noted the importance of other mathematicians when doing mathematics.

> As math students we would hang around in one person's dorm room and stay until 3 am trying to solve a problem and it was just the most fun thing ever. We were all talking about how we could solve the problem. We were working on it cooperatively. We'd work on it together and we'd solve it together. And it was very much a team effort and everybody contributed and it was just this great sense of solidarity that I really haven't found in many other avenues of thought. It was something that very much attracted me to it. I find it very difficult to imagine for myself doing math all the time just by myself.

SHE´S A MATHEMATICIAN

As the project develops, we want to understand how it is viewed by the wider community, and what its impact might be in terms of affecting the images people have about mathematics and mathematicians. One example of the potential impact of the Windows into Elementary Mathematics project comes from using one of the Windows in a fully online math-for-teachers course. The course was offered as an optional summer course for teacher candidates, prior to the start of their teacher education program, and it was advertised as a course for teachers who dislike and/or fear mathematics (GADANIDIS; NAMUKASA, 2009). In fact, many of the 60 teacher candidates enrolled in the course expressed a fear and an anxiety about mathematics. One person provided this summary:

"It is interesting to me that so many of us are admitting that before taking this course we were very apprehensive about teaching math. When the email for this course circulated I felt a jolt of fear and thought, 'Oh no, math!'" The course used WebCT as well as a wiki, and students were organized in 6 discussion groups comprised of 10 students each. The course focused on algebraic thinking and used open-ended problems that could be used in elementary school but could also be extended mathematically to deal with secondary school topics. Students had access to a wide variety of online multimedia resources that related to the problems they explored, including resources from the Windows into Elementary Mathematics project. From a research perspective, data from the course consisted of the online discussions, and themes were identified using content analysis. A unique content analysis tool used was the writing of songs to represent themes that emerged in the data, and these songs were shared with the teacher candidates (Figure 6 depicts one of these songs).

In one of the activities of the course, teacher candidates explored and compared two growth patterns introduced by Lindi Wahl. In her video clip, "Growth Patterns", Wahl uses a simplified two-dimensional model to show how surface area and volume vary as a body grows in size, and what the biological impact might be (GADANIDIS, 2009b)[3]. The model Wahl uses is a yellow square with a green border, constructed using linking cubes (see Figure 5).

Teacher candidates were asked to explore and compare how the inner yellow and outer green linking cubes grow in number. One person noted that "we can see how the border goes up quicker at first, but increases at a steady rate, while the inside takes a while to increase, but then increases rapidly." Another person shared:

> Different growth patterns grow differently. The outside increases steadily by four each time. This growth is steady, constant, and in a straight line. The inside growth starts out more slowly but grows more quickly. Growth on the inside depends on size and has a curved growth.

They were also asked to try to come up with algebraic expressions to represent each growth pattern. Initially, this was quite challenging for most teacher candidates. However, as some people shared the idea that the side of the square might be represented by a letter like a or b, they started generating a variety of expressions. They were surprised to discover that there was more than one way to express the growth patterns algebraically. For example, if the width of the inner square is a, then there are a^2 inner linking cubes and 4a+4 outer linking cubes. However, if a is used to represent the width of the outer square, then the expressions change to $(a-2)^2$ and 4a, respectively. Also, 4a+4 can be written as 4(a+1) and $(a-2)^2$ can be written as a^2-4a+4. One person commented,

3 http://www.fields.utoronto.ca/mathwindows/growth

This exercised has forced me to think beyond my comfort zone and I think that is part of the beauty of math. It forces you to think in new ways which I believe is the key skill gained from studying math. I hope I can inspire this type of thinking in my classroom.

She's a mathematician

She's got a really cool job
Every day a new challenge
Loves to create something new
Loves to "crack" the problem

She's so passionate
Loves the sense of a group
Working together on math
Feels accomplished and proud

She's a mathematician
Applied mathematician
She's a math, mathematician
Applied mathematician

Curiosity and suspense
She's a detective
A math detective
Collecting clues

The winding path
To an elegant solution
She loves the process
And the rigour too

Solves a mystery
Feels accomplished and proud

She's a mathematician
Applied mathematician
She's a math, mathematician
Applied mathematician

FIGURE 6 - Song about mathematician Lindi Wahl.

The teacher candidates read the story "Anno's Magic Seeds" (ANNO, 1983). The story explores various planting scenarios, and the one posed to teacher candidates was as follows: if Anno plants the seed to get 2 seeds, then plants the 2 seeds to get 4, then eats one and plants 3 to get 6, then eats one and plants 5 to get 10, then eats one and plants 9 to get 18, and so on, how many seeds will he have after the 100th planting? They were asked to focus on the solution process rather than the answer.

Teacher candidates explored various solution processes. They started listing the number of seeds that were not eaten after each planting: 2, 3, 5, 9, 17, 33 and so on. Some people thought that the solution involved adding all of these numbers, until someone pointed out that Anno was not storing any seeds he produced, and always planted all of the seeds he did not eat. So the problem became that of finding the 100^{th} number by continuing the sequence 2, 3, 5, 9, 17, and 33. Some people subtracted consecutive terms to see how the pattern grew from stage to stage, and noticed that the growth of seeds involved powers of 2: 1, 2, 4, 8, 16 and so on.

Teacher candidates were also asked to revisit Lindi Wahl's interview and view the video clip "How bacteria grow" (see Figure 5). In this clip, Wahl discussed how the growth of bacteria might be modelled using the exponential growth pattern of 1, 2, 4, 8, 16 and so forth. Teacher candidates made overwhelmingly positive comments about Wahl as a mathematician. One person commented:

> It is evident that she truly loves her job. She enjoys the challenge of creating brand new formulas to explain concepts. She loves collaborating with others who are specialists in their respective fields. She realizes that working with a variety of input from different specialists is most effective when searching for solutions. It appears that she never becomes bored with her work because new challenges present themselves with every new project she works on.

Another person replied:

> I think you make a good point. What she seems to like about math is the challenge. It might be hard, but getting the answer in the end is worth the struggle! I love the way she talks about math! It's great to hear someone talk so passionately about it for once! Lindi also enjoys the inherent beauty in mathematics. She likes being able to condense a huge amount of data into a simple and elegant equation. I really did like how Lindi manipulated the blocks to create the "graphs" of the different growth rates. This was the closest to an "aha moment" as I had. I decided that I definitely need to go out and buy myself a set of those blocks to use!

Their comments, made in the online discussion forum, were compiled to make the song "She's a mathematician", shown in Figure 6 (GADANIDIS, 2009c)[4].

It is interesting that the comments made by teacher candidates about Lindi Wahl were unsolicited. The focus of the activities was on the mathematics and not on Lindi Wahl herself. It is also interesting that teacher candidates who identified themselves

4 http://www.joyofx.com/music/m4t-song6.html

as fearing and/or disliking mathematics would make such positive comments about a mathematician.

CONCLUDING COMMENTS

The research literature shows that both students and adults hold negative stereotypical views of mathematics and mathematicians. The Windows into Elementary Mathematics project offers contrasting perspectives of mathematics and mathematicians, through the words and actions of the mathematicians interviewed: the sensation of beauty, a search for understanding and pattern, an emotional/human endeavour, and collaborative ethos. Mathematicians come across as interesting people who love what they do and who form a supportive, collaborative community. These perspectives disrupt the stereotypes mentioned in our literature review. In fact, when the Windows into Elementary Mathematics project was used in an online course for teacher candidates who identified themselves as fearing and/or hating mathematics, we noticed a significant change in their view of mathematics and mathematicians, as evidenced in the song shown in Figure 6, which summarizes some of their ideas. As one teacher candidate commented, “I have a new found love for math.”

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