In the Friday, September 7, 2007 issue of the Globe and Mail, there appeared on page A17 an article by Elizabeth Church on the use of online instruction at universities. One of the examples described in the article was a series of short cartoons used by Veselin Jungic of Simon Fraser University to support his first year calculus class. Professor Jungic has graciously responded to my invitation to discuss how these films were conceived and how they are are being used.

Math Girl Begins

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1 Introduction

The purpose of this article is to describe the creation and usage of animated movies with calculus themes in teaching corresponding calculus topics.

During the past 40-50 years a steady stream of books and papers on the topic of the use of cartoons and movies in teaching has been flowing. It is an interesting exercise to follow how this activity has been influenced by the development of technology. For example, in 1977 Richard A. Maynard [8] wrote, "Most teachers cannot operate standard 16 mm projectors. At first this meant that they were reluctant to use the films, since many were too proud to admit their technical ineptitude." As a contrast we mention *The Futures Channel Program* founded in 1999 with the mission, "to produce and distribute high quality multimedia content which educators in any setting can use to enliven curriculum, engage students and otherwise enhance the learning experience."[2]

There have been various ways of using cartoons and movies in classes, from starting a class with a cartoon to get students' attention to teaching a full lecture by using previously recorded material. The range of cartoons and movies used in lectures has also been very wide. Editorial cartoons, comic books, feature movies, documentaries, animated movies, or just clips from full length features, have been used to motivate lectures, stir discussion about class topics, enrich otherwise dry subjects and to demonstrate to students some rather abstract aspects of the lecture. It seems that there is not much doubt regarding the benefits of showing topic related cartoons and movies in the classroom. The real issue is still the question asked by Richard A. Lacey in 1972 [7], "What to do when the lights go on?" Reading the available literature does not lead to any universal answer to Lacey's question. It is our opinion that natural science teachers face

a significantly greater challenge than social science teachers in finding the appropriate material for their lectures. Sarah Hughes [4] summarizes the science teachers' dilemma in the following question, ". . . do teachers give students a challenge, or offer less difficult material that is more likely to spark their interest?" Dr. James Kakalios from the School of Physics and Astronomy, University of Minnesota, created a Freshman Seminar titled *Everything I Know About Physics I Learned By Reading Comic Books*. An excellent example of the power of animated movies in teaching scientific topics is *Dr Quantum - Double Slit Experiment*, created by Dr. Fred Alan Wolf [9]. Another rich resource for natural science teachers is the previously mentioned *The Futures Channel Program*.

What about cartoons, comic books, or movies and teaching mathematics? Probably there are not many math students in North America or regular attendees to math seminars that have not seen a cartoon by Sidney Harris or a Dilbert or Fox Trot strip as part of a math presentation. It appears that animated calculus characters have been sadly stereotypical. See, for example, Professor Calculus from the Adventures of TinTin, or Calvin Q. Calculus featured on the Bugs Bunny Show. Dr. Sarah J. Greenwald, Appalachian State University, and Dr. Andrew Nestler, Santa Monica College, have researched the mathematical content in the sitcom *The Simpsons* [3]. A collection of clips with math themes from various feature movies and TV series and shows are collected and posted on the web by Dr. Oliver Knill from the Department of Mathematics, Harvard University [6]. An interesting approach at using (and creating) movies in teaching mathematics was described in [1].

2 Math Girl: Motivation, Goals, and Facts

For many years, lecturing on linear approximation and the differential of a function has been a source of frustration for the author of this note. The topic is usually covered in one lecture and since it requires quite a few technical details, often there is not enough time during the lecture to tell the full story about the big ideas that are behind those technicalities. An additional difficulty in presenting the notion of an approximation to a freshman class comes from the fact that the students are so used to doing all of their calculations on a calculator or a computer. Thus evaluating the square root of thirty-seven with a certain precision is not a *big deal* for them. In the author's opinion, the real challenge in teaching about differentials and linear approximation is to get across the following message. There are advanced mathematical methods that we use to describe, not necessarily exactly but always relatively quickly, some

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complicated phenomena and often we are able to get information about the degree of our imprecision. In Math Girl's words, "Close enough is sometimes good enough."

Motivated by Dr. Jonathan Borwein's remark that "in mathematics sometimes it is easier to see than to say" in early 2004 the author met with Mr. Jesai Jayhmes, an actor and director, to discuss the options of creating an animated video. The original idea was to make a film in which the small image of a math instructor would be seen traveling along the graph of a function and one of its tangent lines. While doing so the instructor would demonstrate the principles and properties of the linear approximation and differentials. This proposal was deemed to be too expensive and the notion of a cartoon was brought up. Next, together with Mr. Lou Crockett, an artist, animator, and designer, Mr. Jayhmes and the author came up with the idea of creating a superhero, who would personify all mathematical knowledge. The choice of a female character was easy. On a midterm in a 500 student strong calculus class, taught by the author of this note in 2002, only one student got 100 per cent and, when the student was asked to stand up, a tiny young woman reluctantly rose in the large lecture hall. Math Girl was born.

Three cartoon movies, *Differentials Attract, Zero!'s Dis-Continuity*, and *Rationalize This!*, about the adventures of Math Girl, a super heroine who uses her super knowledge of mathematics to protect the citizens of Calculopolis from the evil plots of a villain called Zero! have been created so far. Each episode is a short story in which the plot is based on a particular math object and its properties. The episodes are independent of each other. The ambition of the authors of the shorts was to accomplish two goals: to use a pop-culture medium to give a new view (or use) of the well known mathematical objects and at the same time to enrich the medium itself by introducing mathematics as a subject. Mathematics in the movies is strict but not detailed enough to be self-contained. In following with the medium's clichés, the stories are based on the fight between good and evil; where good is a synonym for mathematical knowledge. In her civilian clothes Math Girl is an ordinary student, a smart girl who wears glasses. When she takes her superpower alter ego, thanks to her superb understanding of mathematics, Math Girl becomes a super heroine. Other characters introduced in the Math Girl movies are Math Girl's sidekick Pat Thagoras, a young man who admires Math Girl; professorial Big Math, the mayor of Calculopolis; and Zero!, the evil character whose goal is to rule Calculopolis by exploiting people's ignorance of mathematics. Characters' appearances were inspired by Manga[1] images. The movies might be seen as a benign parody of both the pop medium and scholarship and this makes the audience often react with laughter at scenes. It is a fact that even planning to step outside of the standard delivery of an educational topic requires the involvement of people with various skills and expertise. Also, in its initial phase a proposal of creating a new type of an educational resource must be general and flexible enough to accommodate a range of constraints that may emerge during the process. There are two necessary conditions for moving the project forward. The first is to form a team of people willing to put their talents together towards making a joint product. The other is to secure enough funds to complete the task in a satisfactory manner. To meet those two conditions in academia is not a quick and simple procedure[2].

The biggest challenge for the authors of the Math Girl movies was to find the balance between the necessary mathematics and the flow of the story. The problem could be described as: what to show, what to say, and how to wrap everything up so that the viewer sees beyond three-fingered human-like images. In addition, the intent was to demonstrate to the viewer a range of properties of the particular mathematical phenomenon. The general approach that the authors had chosen was to keep all of the mathematics as simple as possible. This, for example, meant to repeat a catchy phrase that gave the idea of approximation ("Close enough is sometimes good enough"), to loosen mathematical language whenever it was possible ("The differential is very small, so I can easily reach you, Pat"), to materialize mathematical objects ("Square Root Mountain", "Linear Approximator", "Sine T Over T Roller Coaster", "Epsilon - Delta Device") etc. During the process some mathematical details were omitted. For example, a graph showing a differentiable function, its tangent line, together with the increments of independent and dependent variables for both the function and the tangent line, and the differential was part of the script for the episode called *Differentials Attract*. After a long discussion it was decided to omit the graph from the cartoon. The reason was that the information contained in it could not be absorbed in a few seconds, the time that the graph would appear on the screen.

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3 Math Girl: The Lights Are On

It seems that there is no question that the Math Girl movies are entertaining for a student audience. In our view it is not realistic to expect that a 50-minute long lecture can be compressed into a 5-minute cartoon. The math involved is much too quick for students to be able to fully understand the concept being communicated from the first viewing. Thus, the idea is to utilize the Math Girl movies as a complement to the lecture.

The way that the cartoons have been used in the class is to show the short at the beginning and at the end of the lecture. During the remaining 40 minutes, the instructor covers the topic in a standard manner. The purpose of showing the movie at the beginning of the lecture is to give a motivation for the topic and to introduce the basic terms related to it. Also, stories of the first two Math Girl adventures are based on standard examples; therefore the movies contain actual links with the particular lectures. It has been noticed that when students view Math Girl just before the lecture, their participation increases and their general mood is more upbeat and positive than usual. Survey results show that these animated movies have resulted in positive responses from the majority of students, particularly female students. Another effect that the pop medium part of the Math Girl movies has on the young audience is that it de-mystifies the lecture topic. The reason the cartoon is shown again at the end of the class is to demonstrate to the students how much better they understand the mathematics in the cartoon after the lecture. This is also an opportunity for the instructor to underline the main points in the lecture.

The author of this note hopes that a lecture constructed in the described style would excite students' intellectual curiosity and motivate them to look at mathematics not just as a set of technicalities and applications, but also as a playground where human imagination interacts with reality. In the author's opinion that memorable moment of laughter in a calculus classroom justifies the time and effort of a dozen people working for a few months to create one Math Girl episode.

The following email message by a student illustrates the serious side of the effect of the first Math Girl episode, "Until recently, I have heard all my life in mathematics that everything must be exact and precise. So why is it now that we are told, 'Close enough is good enough?'" [5]

Since the first episode was released, Math Girl has taken on a life of her own. Apart from the classroom, the student recruiters from the Faculty of Science and the Faculty of Applied Science at Simon Fraser University have used the first two episodes for the purpose of recruiting. As well, the cartoons have been used to promote mathematics among young people in general. An example is the projection of the first episode during the Canada Wide Science Fair at Science World in Vancouver, B.C., in May 2005. Thanks to YouTube, tens of thousands of people have been able to view the first two episodes. Math Girl has also used her powers to put a graph of the function $f(t) = \frac{\sin t}{t}$ on the front page of The Globe and Mail – a first in the history of Canadian journalism. It has become clear that in front of the general public, Math Girl has been judged not only based on her own merits, but also as a piece of pop culture.

References

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"The Little Match Girl" (Danish: Den Lille Pige med Svovlstikkerne, meaning "The little girl with the matchsticks") is a short story by Danish poet and author Hans Christian Andersen. The story, about a dying child's dreams and hope, was first published in 1845. It has been adapted to various media, including animated and live-action films, television musicals, and video games. The Little Matchgirl is the protagonist of the short film of the same name. The Little Girl's hungry belly after the second match burns out. The short begins with the young girl trying to sell matches on the snowy streets of Russia. Unfortunately, no one will buy them from her, not even a policeman who helps her down from a lamp post. After a day without success, the young girl curls up in a corner with her box of matches in her lap. As the cold winds becomes stronger, she is forced to use one of her Math Girls (æ•°å¦ã‚¬ãƒ¼ãƒ«, SÅ«gaku gÄru) is the first in a series of math-themed young adult novels of the same name by Japanese author Hiroshi Yuki. It was published by SoftBank Creative in 2007, followed by Math Girls: Fermat's Last Theorem in 2008, Math Girls: GÃ¶del's Incompleteness Theorems in 2009, and Math Girls: Randomized Algorithms in 2011. As of December 2010, the series had sold over 100,000 books in Japan.