Mathematical Fiction

Its place in secondary-school mathematics learning

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When a television series like *Numb3rs* (Falacci et al., 2005) is considered worthy of discussion at a recent National Council of Teachers of Mathematics (NCTM) conference it is time to take mathematical fiction seriously. Increasingly, film producers and directors are employing mathematicians as film and television consultants — they really want to get the mathematics right, and they are also using universities like Harvard (A Beautiful Mind) and Caltech (Numb3rs) as locations. In the past successful films or television series have led to a significant upsurge in the numbers of students who opt for various majors, including mathematics, at universities (Devlin, 2005).

This article contains a small selection of mathematical fiction chosen with the teaching of mathematics in secondary school in mind. An attempt is made to classify the works and provide a few ideas about how these items may be used by mathematics teachers, sometimes, but not necessarily, in collaboration with science and humanities teachers, to introduce, teach and supplement mathematics learning (for example, in the discussion of mathematical applications) in secondary schools. The selection includes some simple yet effective picture books and some quite sophisticated ones, film, and a television series.

Traditionally, good primary teachers have known of many ways mathematical fiction, mainly picture books, can be employed in the classroom to engage children in mathematical thinking (Padula, 2004). Senior students can learn mathematics from novels, plays, screenplays and film (Padula, in press). Secondary teachers, although aware of many works of science fiction, may not be as aware of the wider genre: mathematical fiction, defined as science in fiction and including science fiction by Kasman (2005).

There are not very many papers published on the subject but Sriraman (2003) claims that literature can be used to teach cross-disciplinary skills by providing a context for critical thinking, for example: the process of making valid inferences, and problem solving, as well as introducing very sophisticated mathematical ideas. The author relates such positive outcomes from using Abbott's (1932) *Flatland* in a beginning algebra course with 13–14 year-old students.

Sriraman (2004) also found that when the question, "Is mathematics real?" was posed by a student after studying the first five chapters of *Flatterland* (sequel to *Flatland;* Stewart, 2001) that (American) ninth graders could even discuss mathematical philosophy at an elementary level. With these chapters they could also explore mathematics problems, further their understanding of dimension and gain a deeper understanding of fractal geometry.

There are at least seven kinds of fiction suitable for the teaching and learning of real mathematics in secondary school.

Mathematical fiction classics

Flatland by A. Square (Abbott, 1884), *The Time Machine* by H. G. Wells (1895) and *What the Tortoise Said to Achilles* by Lewis Carroll,1894 (a humorous tilt at Zeno's paradox; Guedj,1998) are all examples of literature with mathematics as one of its major themes.

As Stewart remarks in the Preface of his notes on *Flatland*, the book

> is a charming, slightly pedestrian tale of imaginary beings: polygons who live in the two-dimensional universe of the Euclidean plane. Just below the surface, though, it is a biting satire on Victorian values — especially as regards women and social status — and an accomplished and original piece of scientific popularisation about the fourth dimension (Abbott & Stewart 2002, p. ix).

Flatland is a guide to the geometry of space-time and relativity, and a clever social commentary (Renz, 2002). Very much tongue-in-cheek, Abbott's book must be among the first mathematical-fiction books by a man with a decidedly feminist perspective. It is a classic that has lasted, because, as Stewart states (Abbott & Stewart, 2002), a twenty-first century reader can identify with "A. Square" and his lonely battle "against mindless orthodoxy and social hypocrisy" as easily as a nineteenth-century one. Studying Stewart's annotated version is a must for interested mathematics teachers.

In a foreword to the 1931 (fourth) edition, Wells declares that *The Time Machine* is a very unequal book — the early discussion is much more carefully planned and written than the later chapters. He claims his one idea was that time is a fourth dimension and that the

> normal present is a three-dimensional section of a four-dimensional universe. The only difference between the time dimension and the others, from this point of view, lay in the movement of consciousness along it … a method of stating the conception of relativity that did not come into scientific use until a considerable time later (Wells, 1931, p. VIII).

In his book, Wells, like Abbott, explores class inequality, as well as evolution and the relationship between science and society. Both *Flatland* and *The Time Machine* are available free online.

Modern updates of mathematical fiction classics

Flatterland (Stewart, 2001) introduces more up-to-date dimensions of space-time, up to a ten-dimensional supermanifold (Collins, 2004). One of the modern versions of *Flatland* (see Abbott & Stewart 2002 for a list) Stewart's *Flatterland* contains descriptions of non-Euclidean geometries from topology to projective and fractal geometries, and conversational, question-and-answer explanations of phenomena such as black holes — regions of space-time from which nothing, not even light, can escape (Abbott & Stewart, 2002). It is full of amusing puns and is reminiscent of both *The Time Machine* and *Alice's Adventures in Wonderland*, as Stewart's heroine, Vikki (Victoria Line), visits the Fractal Forest and other geometries with her guide, the Space Hopper and his machine — the Virtual Unreality Engine (VUE).

The following is an excerpt from Chapter 12, The paradox twins, as the Space Hopper explains to Vikki why Einstein's Special Theory of Relativity is misnamed.

> "…our old friend Alberteinstein — yes, the People who realized that light can behave like a particle — used that one simple fact as the basis of an entire theory of Spacetime. He called his theory 'Relativity'."
> "Because it said that everything was relative?"
> "Pretty much the exact opposite! The main thing to remember about Relativity," said the Space Hopper, "is that it's an extraordinarily silly name."
> "Then why use it?"
> "Historical accident," said the Space Hopper. "The Planiturthians are stuck with it. The whole point of Relativity is not that 'everything is relative' but that one particular thing — the speed of light — is unexpectedly absolute."
> (Stewart, 2003, p. 191.)

Stewart gives an accessible summary of

both the Special Theory of Relativity and the General Theory of Relativity (gravity is a result of the curvature of space-time) in his annotated book on *Flatland* (Abbott & Stewart, 2002, p. 14)[1]. In his notes, Stewart (ibid) mentions that Einstein's Theory of Special Relativity is discussed in Chapter 12 of *Flatterland* and the first part of Chapter 13, "Domain of the Hawk King". The rest of Chapter 13 and Chapter 14: "Down the Wormhole", contains an explanation of Einstein's General Theory of Relativity.

Understandably then the chapters 6 to 18 of *Flatterland* were thought too difficult for Sriraman's (2004) 13–14 year-old students, but some chapters (before Chapter 12) may be suitable for older students. As an example, Chapter 7 is a good aid for teaching projective geometry, an interesting aspect of the progression from cartesian to polar coordinates in trigonometry (usually taught in Year 9 in Australia); see Anno's anamorphic art section of *Picture books*.

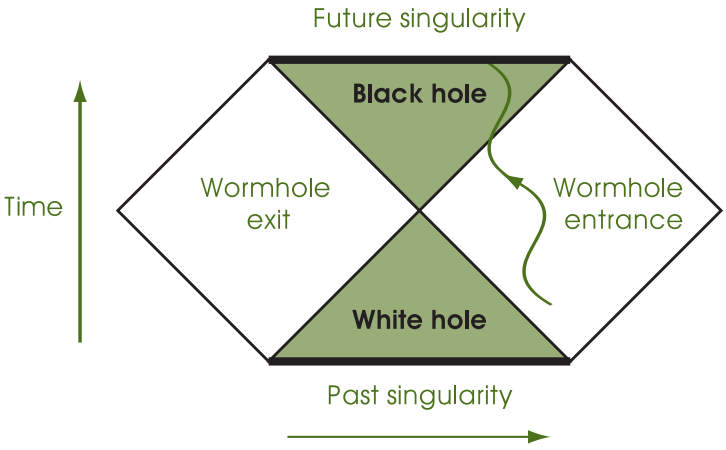

Figure 1. Roger Penrose's map of a spacetime from Flatterland by Stewart with the permission of Macmillan (Stewart, 2001, p. 237).

Flatterland also contains many simple black and white diagrams that illustrate Stewart's explanations. See Figure 1 for Penrose's conception of a space-time that includes a black hole.

Updates of *The Time Machine* are many, too numerous to mention and include episodes of the *Dr Who* and *Star Trek* television series. Recently Kasman (2005) stated that Wells' novel is the basis of (at least) three motion pictures and has inspired many others, as well as many novels and short stories.

Picture books for secondary-school students

Books suitable for mathematics task centres and lower-form mathematics classes

There are only a few picture books on Kasman's (2005) list of mathematical fiction, they are: *The Phantom Tollbooth* (Juster, 1961), the "highly rated" *The Dot and the Line* (Juster, 1963, 2001) and *Maths Curse* (Scieska & Smith, 1998). *Maths Curse* is an amusing, colourful, well-designed book about problem solving, as is the only Australian picture book included: Clement's, *Counting on Frank* (1991).

Norton Juster (2001) writes brilliantly of a lovesick line in his picture book on geometry, *The Dot and the Line*. This mathematical fiction classic was made into a short, animated Academy Award-winning film in 1965 by Chuck Jones (Goldman & Jones, 1965). Challenging, but not impossible to find, the film, like the book, is well worth a search on the Internet.

More sophisticated picture books

The Japanese illustrator and former teacher Matsumasa Anno has produced many books with mathematical themes. *The Mysterious Multiplying Jar* by Matsumasa and his son Masachiro Anno (1983), and *Anno's Hat Tricks* by Nozaki, a mathematics professor, and Anno, (Nozaki & Anno, 1985) are just two of these books.

For students who learn primarily through the visual mode, *Anno's Mysterious Multiplying*

1. In *The Annotated Flatland* Stewart explains that relativity is really about the physics of events. In traditional mechanics a particle moving through space occupies coordinates $(x(t), y(t), z(t))$ at time t, and this position changes as time changes.
From Herman Minkowski's (1864–1909) space-time viewpoint, the collection of all such points is a curve in space-time, the "world line" of the particle. The most important new ingredient in relativity is that the appropriate measure is not
$$\sqrt{x^2+y^2+z^2+t^2}$$
as it would be in standard four-dimensional Euclidean space, but
$$\sqrt{x^2+y^2+z^2-c^2t^2}$$
where c is the speed of light, an absolute 300 000 kilometers per second. This quality that is called the interval emerges from James Clerk Maxwell's equations of electromagnetism (Abbott & Stewart, 2002, paraphrased). For more about Maxwell and his equations read Arianrhod's 2003 book, *Einstein's Heroes*.

Jar illustrates the concept of factorials (4!, 3!, 2!, etc.) imaginatively and is a splendid lead-in to probability. Through the device of what may be found inside a beautiful blue and white jar, rippling water becomes a wide sea, the sea has one island consisting of two countries, within each country there are three mountains, and so on. For those students who learn best with a verbal (or written) presentation Anno provides an *Afterword: A little more about factorials*, a detailed, written explanation at the back of his book.

Anno's Hat Tricks (Nozaki & Anno, 1985) teaches binary logic (the basis of computing), and notes, including a tree diagram and an explanatory flow chart, can be found at the end.

Anno's anamorphic art, paradox and trigonometry

In *The Unique World of Mitsumasa Anno* (1980), Anno explores mathematics, science and paradox with illustrations of topics such as "anamorphic art". Anamorphic art is a technique of extreme perspective distortion in painting or drawing (a shadow is a good example) and is part of projective geometry — a non-Euclidean geometry. As previously mentioned, projective geometry is discussed in detail in Chapter 7, "Along the looking glass", of Ian Stewart's (2001) *Flatterland*.

With a small sheet of mylar (shiny metalised plastic available from archive-supplier shops in Australian capital cities) rolled into a cylinder, or, as Anno suggests, a highly reflective jar or tea caddy, students can view samples of anamorphic art, like the thief's image from Anno's (1980) book *The Unique World of Matsumasa Anno* (see Figure 2 for Anno's illustration, and Figure 3 for its reflection on a jar).

Students may draw an object on graph paper and then transpose the appropriate parts of their drawing into the corresponding sections of a stretched, curved grid; or they may experiment with computer software, such as Adobe *Photoshop*, to produce an anamorphic version of a picture previously drawn or painted, photographed, and scanned. A search on Google for the following site: Anamorphic Art Maths Year 2000, (then choose: cylindrical mirror anamorphosis) will reveal examples of

Figure 2. Plate 31: Anamorphosis, from *The Unique World of Matsumasa Anno* (Anno,1980, p. 37).

Figure 2b. Anno's thief from, The Unique World of Matsumasa Anno (Anno,1980, p. 37) Plate 31, Anamorphosis, and its reflection on a shiny, cylindrical jar. Published with permission from the Japanese copyright holders Kodanska. Image: Daniela Padula.

anamorphic art, plus ideas for teaching it, and free software alternatives to Photoshop such as *The Gimp* (for PCs and Mac OS X). The instructions include directions for making an exact, mathematically correct anamorphic image that involves a mapping or correspondence between a cartesian and polar set of coordinates.

Anamorphic Art at
http://hs.housetonisd.org/debakeyhs/Lessons/anamorphicart.html
reveals that some American teachers regard anamorphic art as an interesting progression from cartesian to polar coordinates in trigonometry and are willing to grant one hour of curriculum time to it.

Also, the picture book *The Magic Mirror: An Antique Optical Toy* (McLoughlin Bros, 1979) is very reasonably priced and available on order from children's bookshops. It contains 24 examples of anamorphic art (from an antique set in the Gold Collection at the Museum of the City of New York) and a sample sheet of mylar that can be rolled into an anamorphoscope (a reflective cylinder — a very popular children's toy in the nineteenth century) for the viewing of this mathematical artistic oddity.

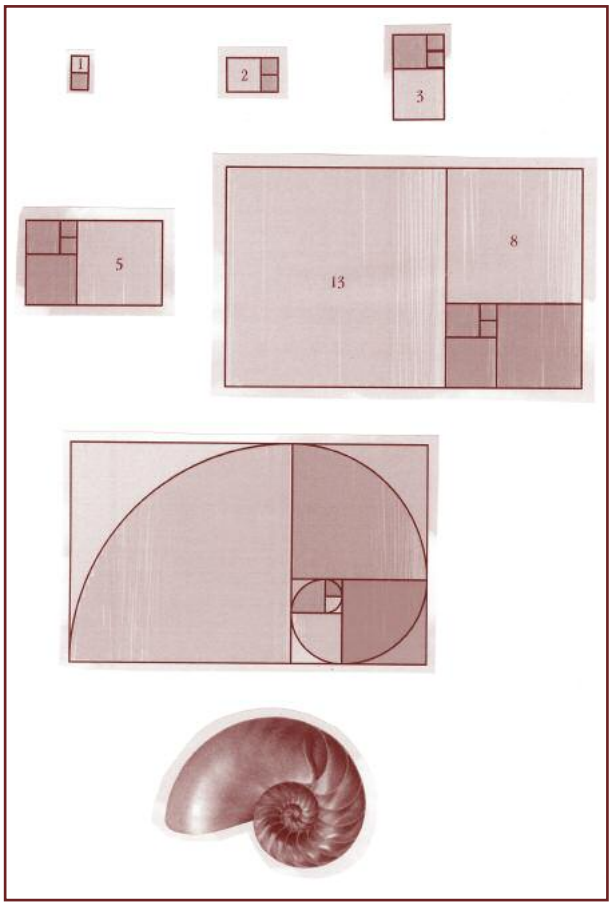

Figure 4. The snail-shell diagrams from Fibonacci's Cows (Galvin, 2001, pp. 22–24, with permission of Mimosa Shortland).

Illustrated bridging novels

Illustrated bridging novels, that is, children's first "chapter" books, such as *Fibonacci's Cows* by Ray Galvin (2001), are relatively easy to read for Year 7 and 8 students. Ryan has not handed in his mathematics homework so his teacher gives him a special assignment: he must give a talk on "Fibonacci's cows" in class the next day or miss the biggest soccer match of the year. Firstly Ryan searches the Internet, then he falls asleep and dreams about an old man called Leonardo (da Pisa, aka "Fibonacci") who discusses and displays rabbits' breeding patterns, the spiral pattern in a sunflower, the pattern in a snail's shell, the reproduction of honeybees, and the branching of a sneezewort plant. After reading this book Year 7 or 8 students could discuss Fibonacci numbers, read the notes on the golden number and the golden angle at the back of the book, and reproduce the snail-shell diagrams (pp. 22–24) on paper with a pencil, compass and ruler.

Illustrated novels for teenagers with mathematics as a major theme

A novel in this class is the bestseller *The Parrot's Theorem* by Denis Guedj (2000), a professor of the History of Science at a Paris university and teacher of fictional approaches to science. This is a very ambitious book as it encompasses a history of mathematics within a detective story — namely, where is the solution to the missing theorem (Fermat's Last Theorem) and why was the dead mathematician's parrot kidnapped? Achievements of famous mathematicians are detailed within the central story of teenage twins and their 12-year-old adopted, deaf brother, their single mother, and her employer, Mr Ruche, the elderly owner of a Parisian bookshop. Sometimes found in the adult section of local libraries, the book was written for teenagers and anyone interested in the history of mathematics.

Guedj has varying degrees of success in combining history of mathematics tales within the detective story; most chapters are successful but as the mathematics becomes complex and in need of more explanation, a few chapters have an interrupted feel. Readers can become so absorbed in the mathematics history stories that they return reluctantly to the main storyline, until the central plot becomes more exciting towards the end. The tales from the history of mathematics are illustrated with simple black and white diagrams of the contributions of various mathematicians from Thales and Archimedes, to Fermat, Boole, Cantor and Hilbert. The diagrams in Figure 5 show how Thales measured the height of the Great Pyramid of Cheops by using the shadow cast by the Pyramid on one special day of the year, a piece of rope, and a unit of measurement: the Thales, his height.

As Guedj remarks the relationship between the heights and lengths of the triangles can be written as:

$$\frac{\overline{OT}}{\overline{OP}} = \frac{\overline{OT'}}{\overline{OP'}}$$

OTT' and *OPP'* are similar triangles.

The narrator, Christopher, of *The Curious Incident of the Dog in the Night-time* (Haddon, 2003) has Asperger's Syndrome. Christopher, fifteen years, three months and two days old, is about to sit for his English A levels in mathematics, although he has great difficulty relating to people, hates being touched, cannot understand complexities of language such as metaphors, and will not eat foods that are yellow or brown. (Chapter numbers are prime because Christopher likes prime numbers and there are interesting mathematical asides with black and white illustrations, and maps and diagrams throughout the text.) An English A-level calculus problem mentioned in the main body of the novel is repeated and answered in the appendix. It is:

> Question
> Prove the following result:
> "A triangle with sides that can be written in the form $n^2 + 1$, $n^2 - 1$ and $2n$ (where $n > 1$) is right-angled."
> Show, by means of a counter example, that the converse is false. (Haddon, 2003, p. 269)

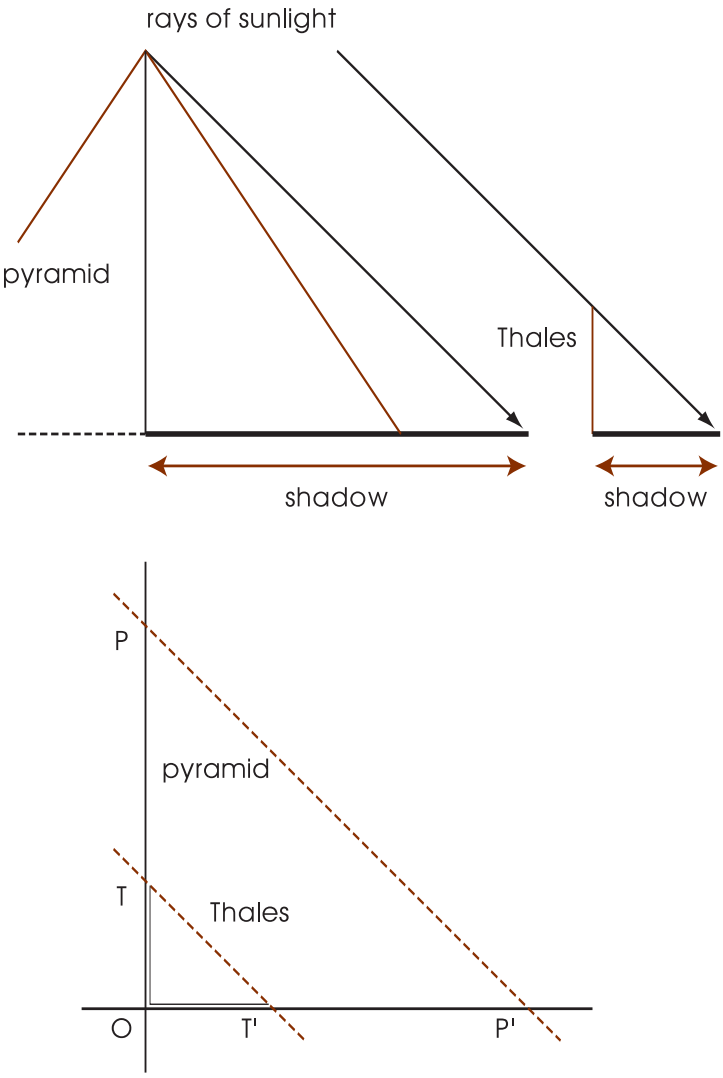

Figure 5. How Thales measured the height of the Great Pyramid of Cheops, from Guedj, 2000, p. 39, with permission from Weidenfeld and Nicolson, publisher.

The problem is based on Pythagoras' theorem of the area of the hypotenuse of a right-angled triangle, etc. (currently learned in Year 9 in Australia), so it is suitable for Year 10 students and upwards. The novel is written in the first person and the long and breathless sentences reflect the way Christopher speaks, so that his voice is clear and strong and the story highly engaging for both teenagers and adults.

The novel succeeds in breaking down some of the ignorance surrounding autism. Indeed, it succeeds on three levels as a realistic story of a family in crisis, a detective story (who killed the dog?) and an introduction to mathematical thinking. It was winner of the Whitbread Book of the Year prize, and deservedly so.

Translated from the German, Enzensberger's (1998) novel *The Number Devil* is also certainly worth considering as an illustrated story about mathematics: a young boy dreams each night of the Number Devil who explains and colourfully illustrates different aspects of number theory — combinations and permutations, integers, irrational numbers, prime numbers, and so on. Famous mathematicians are given new names and this is annoying, but there is a list of real names at the back of the book.

Novels for teenagers without illustration and with a minor or major mathematical theme

Books of this kind include *Rain Man* (Fleischer, 1989) and *Getting Somewhere* (Pausacker, 1995).

In *Rain Man*, Charlie Babbit (Tom Cruise in the film of the same name) tries to secure the inheritance of his autistic brother, Raymond, by absconding with him across America. In Las Vegas, on the way home to Los Angeles, Charlie uses Raymond's photographic recall of numbers to win a large amount of money at the gaming tables. Watching a scene or two from the film on video or DVD can precede lessons on probability in gaming.

Getting Somewhere (Pausacker, 1995) tells the story of Dinah, a partially deaf twin, who has missed out on a whole year of schooling because of illness and feels she is behind academically and socially. An encouraging mathematics teacher gives her a Year 12 Further Mathematics work requirement:

> Work requirement. Investigate the behaviour, for different choices of x_0, of the difference equation $x_{n+1} = \sin x_n$. (Hint: Start with $x_0 = 0$. Then try x0 = $\pi/2$. Use a calculator to find successive values of sin x_n.)
> (Pausacker, 1995, p. 107)

followed by a project based on chaos theory.

The *Chaos Project* entails investigative exercises of the Logistic Equation: $x_{n+1} = rx_n(1 - x_n)$, used to model specific types of population shifts; it has fixed points for some values of r but is chaotic for other values of r (ibid).

Dinah uses her scientific calculator, persistence, and her growing confidence to find the pattern in the (seemingly) chaotic numbers. The book was short-listed for the Children's Book Council of Australia Awards, and Australian mathematician, author and university lecturer Robyn Arianrhod checked the work requirement and investigative exercises for Pausacker, collaborating with her on the writing of the sixth chapter.

Film and a good television series

Numb3rs (Falacci et al., 2005) may attract teenagers initially because of its two handsome male protagonists (a detective and his brother Charlie, a mathematician) but the mathematics it contains is derived and inspired by true stories of police detection using real mathematics. For a detailed discussion of the mathematics used in the series see Devlin (2005) and Kasman (2005). Kasman's site in particular is excellent since it includes an episode guide to the mathematics with links to sites with even more information. Some episodes will be more useful for secondary school students than others, although generally the episodes may be suitable for Years 9 to 12.

"Counterfeit reality" (Dettman, 2005), Episode 1.07 is about how analysis of graphical elements on many scales at once is used in art authentication and includes mention of probability and combinatorics. Episode 10 of the first series discusses game theory, a topic that is also explored in scenes from the film *A Beautiful Mind* and would be suitable for senior students (Padula, in press).

Practicalities

After reading and viewing even a small selection of mathematical fiction mathematics teachers will discover that ideas for teaching using these books, films and television programs are as limitless as their and the authors' imaginations. Mathematical fiction reflects and affects the world of non-mathematicians (Kasman, 2005). It is often not meant to be taken seriously, but perhaps it should be — especially by mathematics teachers, since the popularisation of mathe-

matics is important, teachers often have to sell mathematics to their future and present students, and, most importantly, these works represent a great teaching resource that can encourage mathematical thinking by capturing the imaginations of students. It is also good to acknowledge that mathematical fiction has long existed, is growing, occasionally needs correction, and can easily stimulate discussion of new (and old) mathematical ideas.

However, if teachers feel there is no time in mathematics classes for even a small selection of book sections, short stories, scenes from films etcetera, perhaps in the spirit of interdisciplinary education English, Library, Science and Art teachers may be persuaded to introduce some in their classes, or collaboration on some topics may be possible.

Such works may stimulate the interest of reluctant mathematics learners, reinforce the motivation of the student who is already intrigued by mathematics, introduce topics, supply interesting applications, and provide mathematical ideas in a literary and at times, highly visual context. They are a way of humanising mathematics and introducing topics in an engaging and accessible frame. The very best mathematical fiction can add humour, mystery, romance, drama, history of mathematics and art, vigorous debate and literary appreciation to your teaching. With thoughtful selection and careful teaching, this body of creative writing can also help explain mathematics topics to students. Perhaps you have your favourites already and are willing to share them with colleagues?

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