
THE
HUNTING
OF THE
SPARK

Abstract

Lewis Carroll and Charles Dodgson, two men packed into one body in much the same way as the author would pack two meanings into one word in his stories. Martin Gardner, the populist mathematics and science writer, suggested that Carroll's poem, *The Hunting of the Snark*, may, in part, have been a satirical autobiography. Taking this proposition *as the subject to reason about* we use the poem as a mirror to examine what elements, or fits, are needed to provide the elusive spark for effective mathematics learning and teaching.

The seminar, like the classic poem, is divided into a Preface and eight fits:

Fit (the First): The Landing (in the Classroom)
Fit (the Second): The Bellman's Speech (the nature of students)
Fit (the Third): The Baker's Tale (Who are You?)
Fit (the Fourth): The Hunting (The Language you speak)

Fit (the Fifth): The Beaver's Lesson (the teacher student relationship)
Fit (the Sixth): The Barrister's Dream (do not defend the indefensible)
Fit (the Seventh): The Banker's Fate (learn from others even while you teach)
Fit (the Eighth): The Vanishing (of Teachers from the profession)

Before reading this essay it is highly recommended that you first familiarise yourself with Lewis Carroll's poem, The Hunting of the Snark as it has been the looking glass into which the author has gazed throughout the writing process. It is also a wonderful piece of nonsense to simply become lost in and enjoy!

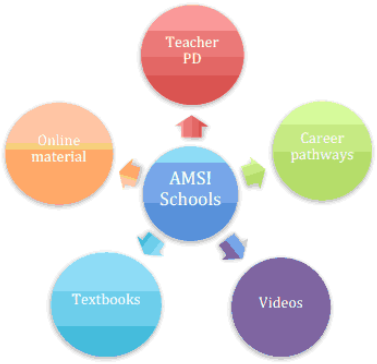
About AMSI (The Australian Mathematical Sciences Institute)

AMSI was founded in 2002 in response to a need for collaboration in the mathematical sciences to strengthen mathematics and statistics especially in the universities. From its inception AMSI has aimed to support research at all levels including mathematics in cross-disciplinary areas, business and industry; enhance the undergraduate and postgraduate experience of students in the mathematical sciences and cognate disciplines; and to improve the supply of mathematically well-prepared students entering tertiary education.

AMSI is an un-incorporated joint venture between The University of Melbourne, Monash University, the University of New South Wales, The Australian National University, RMIT University, Latrobe University, the University of Queensland, the University of Adelaide, the University of Newcastle, the University of Sydney and the University of Western Australia. In addition to these core members, AMSI membership includes most tertiary institutions across the country as well as the Australian Mathematics Trust, the Bureau of Statistics, the Bureau of Meteorology, DSTO and CSIRO."

AMSI has three division: AMSI Schools, AMSI Intern and Research and Higher Education. Detailed descriptions of what each of these divisions offer can be found at the organisation's website www.amsi.org.au

The AMSI Schools team provides professional development sessions and school visits across Australia. Together we look at how to best communicate mathematics to your students and source engaging classroom activities to capture and stimulate creative mathematical minds.



AMSI Schools division delivers a multi-faceted program devoted to encouraging more Australian students to study and enjoy mathematics throughout their school years and into university.

The vast majority of our work with schools is funded by grants from government and industry. Funding partners in the 2013-2104 round of projects were Boeing, The William Buckland Foundation, the DEECD and AMSPP.

About Michael O'Connor

From 1988 until October 2013, Michael taught mathematics and science at a number of secondary colleges in New South Wales and Victoria. Since October Michael has been the Schools Outreach Manager for AMSI. In the last twelve months, he has worked with more than 200 teachers from kindergarten to senior secondary in 24 schools around the country. This work has included modelling classes, observing and providing feedback, unpacking the curriculum, planning and professional development. It has been a very insightful period. This essay is in many respects a reflection on twenty-six years of teaching, learning and hunting for the spark that can strike a light for students and teachers alike.

The Preface

Charles Lutwidge Dodgson was both an author and a mathematics teacher. He was many other things besides, but for the purpose of this essay it is his writing and his teaching that provide us with the best mirrors with which to seek our elusive Spark.

As an author we know Dodgson better by the pen name Lewis Carroll. It is from his story "Alice in Wonderland" that the theme for this conference derives. Apparently, Queen Victoria was so enthralled by this book that she demanded that whatever Carroll's next book should be, she wanted a copy. That next book turned out to be *An Elementary Treatise on Determinants*. One can well imagine the great lady invoking her most distinguishable aphorism upon the tome's arrival.

As a teacher, Dodgson was primarily a lecturer in mathematics at Christ Church in Oxford. He held this post for twenty-six years between 1855 and 1881. There was also a short period where he taught in two separate schools in 1855 and again in 1856. It would be fair to say that after the second experience he vanished from the classroom, never to return.

Among Carroll's works, *The Hunting of the Snark* is unique in that it has come to be seen, at least in part, as a satirical autobiography. As such it should then be expected that hints and allusions to Dodgson's experiences to teaching of mathematics are included in the work. It is this premise that forms the basis of the current essay and provides a guide for reflecting on our own experiences as well.

For those unfamiliar with Carrollian scholarship, there is a long tradition of trying to elicit sense and meaning from the nonsense poem that is the *Snark*. Carroll himself is on record several times about it. Martin Gardner (Carroll, 2006) records that in 1896 Carroll wrote:

> "I'm very much afraid I didn't mean anything but nonsense! Still, you know, words mean more than we mean to express when we use them: so a whole book ought to mean a great deal more than the writer meant. So, whatever good meanings are in the book, I'm very glad to accept as the meaning of the book."

Adam Gopnik, in his introduction to the annotated edition (p xvii, 2006) notes that:

> "the Snark is a surrealist text … whose local details all make sense and whose global meaning makes none."

The first meaning that we may draw from the poem then is that it is a metaphor for the experience of many mathematics students where small parts of the subject make sense in isolation but are often not resolved into a coherent whole. At such times the effect is to feel as though we are going in circles backwards, a condition that is achieved in *The Snark* by attempting to steer to starboard while keeping the ship pointing larboard (to port). In any effect it is disconcerting and nauseating..

Gopnik continues (p xx), by saying that "we live in a world not of our making that our imaginations help to make". This is true not just of the poem but also of mathematics. It is by the use of our imagination that mathematics is made, and it is also by imagination that meaning can be made of mathematics that has been created by others. Imagination is the element needed "for striking a light", a Spark if you will, in the minds of our students.

Whatever good meanings are in the book that relate to the teaching and learning of mathematics we will now explore.

Fit the First: The Landing (in the Classroom)

The classroom is just the place for a spark. It is here that teachers and students meet to become "well acquainted with matters mathematical". It is the role of the teacher to lead students through experiences that increase understanding and fluency in mathematical techniques while also providing them with the opportunities to apply their skills to successfully reason about the world and solve problems they encounter within it.

So, what are the attributes of a good mathematics teacher?

It is worth reiterating here that Snark is seen as a satirical autobiography of Carroll. Being satirical Carroll has no qualms about describing himself in unflattering terms. In the character of the Baker, Gardner (2006) sees most clearly Carroll's own description of himself with an "ungainly form" and a "small intellect" despite being known for all manner of things. Carroll presents us with a warts and all picture of himself. This brusque honesty is the first quality of a good teacher of any subject: one who does not take themselves overly seriously and is aware of their shortcomings as well as their accolades and achievements.

So as not to seem unbalanced or unduly negative, the other half of Carroll's description of the Baker states that "his courage is perfect! And that after all, is the thing that one needs with a Snark". Teachers possess courage by the bucket load. Courage to experiment and improvise, engage and elucidate on a daily basis.

Looking briefly at each of the members of the ship's crew we can discern a number of other characteristics and roles necessary for a teacher. Some of these are functionary while others are essential to good instruction. The summary given here is provided to serve as a looking glass for each of us to reflect on our own qualities as teachers.

Introduction of the crew: The Roles and Qualities of a Teacher

Name	Description	Correlation to Teaching
The Bellman	Town Crier and Captain who "tingles the bell"	Teachers lead but are also governed by the bell, having to deliver material to a strict timetable.
Boots	Servant and Helmsman	Entrusted with steering students toward learning and growth
Barrister	To arrange their disputes	Maintaining order, behaviour management.
Broker	Appraiser and seller of household goods	Assessor of the quality of students' work
Billiard Marker	Keeps record of points scored in a game.	In the 21st Century we can allude to the sheer volume of record keeping necessary in the role. In earlier times, the connection of the use of chalk in both professions was prominent.
Banker	Engaged at enormous expense (reminiscent of Victorian Music Hall introductions for the star attraction)	Here there is the double allusion: firstly to a profession that works with numbers on a daily basis and secondly to the qualities of showmanship in teaching.
Beaver	That paced on the deck or made lace in the bow	Teachers "pace" the floor of classrooms. Lace making is threading together patterns to show a coherent picture or to join otherwise unrelated parts together. Teaching is also about lacing ideas together.
Baker	"His form was ungainly, his intellect small" and he had 42 boxes of belongings	Often the first two of these are descriptions of teachers by students. The possession of 42 boxes can be seen as an observation that

		we all come to the profession with our own baggage and that over time much of it needs to be jettisoned if we are to progress.
Butcher	A dunce with only one idea	Sometimes we can "butcher" an idea and rather than promoting student learning we kill it off. This is something that all teachers need to be wary of and guard against.

Actions and Behaviours

Hattie (2009, 2012 and 2013) describes three levels of teachers: novice, experienced and expert. He does not look at expertise solely in terms of teaching but across a wide variety of careers and other fields of endeavour. The research evidence he presents shows that there are significant differences in performance associated with these three levels. He also notes that whatever the field of an individual's expertise it comes after decades of effort and deliberate conscious practice aimed at improvement.

In recent years there has been considerable debate about performance pay for teachers, with the implication being that if teachers want to be paid more, then they will teach better. This is a simplistic notion. No-one likes to think of ourselves as "below average" and forcing people into such moulds can be counter-productive because the very definition of average however means that half of the population always will be, in one way or another. Rather than focus on our current ability level it is more advantageous to seek to improve continually whether this be by using "*thimbles and care", "forks and hope", "railway shares", "charm"* or *"soap"*.

The AMSI approach to teacher professional development is to meet teachers at their point of need, to offer a variety of materials, resources and support that enables teachers of all experience levels to continue to grow, develop and improve. We strive to help all of the teachers we come into contact with become comfortable in their own skin and thus make the classroom truly their own, where they feel free to roam all areas rather than staying safe at the front and "*appear*(ing) *unaccountably shy*."

So then, what are the attributes of expert teachers? Hattie and Yates provide two descriptions that are worth pondering:

First:

> "Expert teachers have high levels of knowledge and understanding of the subjects that they teach, can guide learning to desirable surface and deep outcomes, can successfully monitor learning and provide feedback that assists students to progress, can attend to the more attitudinal attributes of learning (especially developing self-efficacy and mastery motivation), and can provide defensible evidence of positive impacts of the teaching on student learning. Herein lies the differences between the terms 'expert' and 'experienced'." (Hattie 2012).

Second: "when experts are compared to novices:

- Experts excel only in their own domain.
- Experts perceive large and meaningful patterns.
- Experts can work quickly and solve problems with little error.
- Within their domain, experts possess remarkably large short-term memories.
- Experts see and represent problems at a deeper or principled level, whereas novices focus on superficial aspects.
- Experts spend relatively more time analysing problems carefully and qualitatively.
- Experts have strong skills in self-monitoring." (Hattie, Yates, 2013).

When we, as teachers, land in the classroom these are the qualities and behaviours we should strive for. They are the first ingredients for producing the elusive Spark in our students.

Fit the Second: The Bellman's Speech (on the nature of students)

So if the image of what a teacher looks like can, to some extent, be gleaned from the first fit, what then can we say about the nature of students?

Carroll says that *"common Snarks do no manner of harm but some are boojums".* So too, the common form of student does not give much trouble to teachers, but some cause us to faint at the thought of them. Some of this is due to behaviour but it can just as often be from their difficulty with grasping the concepts we are trying to impart to them. In order to engender a spark of understanding to all of the students we teach, we as teachers need to understand students both collectively and individually. Engaging with them in conversation provides us with opportunity to elicit feedback into how they are going and where they, as individuals, need assistance. This is the essence and focus of formative assessment. We need to build up a picture of what each student looks like so that we can both navigate their minds but also steer them toward a course for success. Relating this to the poem, the Bellman's description of the five unmistakable marks of a snark are:

One explanation for the origin of boojum is that it can be found in "mum*bo jum*bo". It is, unfortunately, many people's experience that mathematics is just so much *mumbo jumbo.*

- their *taste*, which while at the surface level refers to how the taste when cooked can also be interpreted as their taste in fashion.
- *their habit of getting up late*
- *their slowness in taking a jest*
- *their fondness for bathing machines* and finally
- their *ambition*

In Fit 5 of the poem the Butcher provides another five-point description, this time of the qualities of a Jub Jub.

- Its *taste in fashion*,
- Being in a *state of perpetual passion*,
- It knows its friends, (and will joke with them but not outsiders)
- It is above bribery (it is in this sense "clean" of corruption)
- It is willing to volunteer for all manner of causes but does not commit (it possesses ambition but lacks commitment needed for stablishing change.) (Carroll, 2006)

The similarity of these lists to each other hints that they should be taken together to provide a more holistic image. Many of the individual qualities also quite aptly describe the more obvious attributes of modern teenagers! As teachers we need to continually be identifying the marks of students and adapting our teaching to fit their needs.

Some readers may feel at this point that statements like this unduly place the onus upon teachers to the exclusion of the other players in the educational setting, especially the students. This is not the intent. Rather, as a teacher, speaking to teachers, all we have control of in the end is what we do and say in the classroom. We can exhort students, parents and politicians to do their part but cannot force them into it.

When looking into the needs of students teachers do well to consider that the deficiency displayed by students may not be a one that resides within the student. John Mighton (2003) counsels that "if your students are not successful in mathematics, look not to deficiencies in the student, instead look to how you can change your practice".

Fit the Third: The Baker's Tale (Who are you?)

So, how do we meet the needs of students? We need firstly, to develop within ourselves a robust capacity for reflection and metacognition, thinking about what we are thinking and doing. The Third Fit says much the same thing. He, the Baker, first tries to impress his audience with personal history, to which the Bellman cried "Skip all that!" It is not our personal history that matters in the classroom. He then alludes to his pedigree which meets with similar dismissal. It is only when he talks about becoming one of the company that they listen to his story. So, for us as teachers, it is what we do and say in our quest for learning that is important. What students are interested in is how we as teachers interact with them.

In order to develop a capacity for objective comparison of our own performance it is necessary to put in place a daily routine whereby we ask ourselves a series of reflective questions. We need, like the Baker to *engage with (the Snark)… every night after dark …and use it for striking a light.* This approach to learning has a long tradition, going back at least to Socrates who believed that the "unexamined life was not worth living". Dean et al (2012) follow on from Marzano's (2001) work and provide a comprehensive insight into classroom instruction that works including such reflective procedures.

In addition to this and other similar works I submit a set of reflective questions that can be printed on a single sheet and used to focus the mind on the immediate past performance of a day's lessons.

They are:

- How did that (lesson) go?
- What parts worked (particularly) well?
- What parts did not work well?
    - What can I do next time to correct this?
- Did I interact with each student in the class by
    - Asking questions of individuals
    - Giving each of them an opportunity to contribute to the lesson
    - Guiding them toward deeper understanding and engagement
- How did the students interact with each other?
- How often did I seek feedback from the students and check for understanding
- Was there anything left unanswered that I can follow up on next time?
- Where there any opportunities for incidental and/or remedial teaching?
- Where did I physically spend my time?
    - What were the reasons for this? How aware was I of this at the time?
    - How did I spend my time in these locations? Was I waiting? Was I observing and monitoring progress and performance.

These questions are by no means exhaustive but they are a start. For those unaccustomed to such reflection it can seem tedious and a burden on an already busy day. I assure you however, that over time it becomes automatic and it does lead to continuous gradual improvement in teaching practice.

So what was Dodgson like as a teacher? We know he could entertain, particularly in his stories. We also know that he was a reasonable mathematician. As to his ability to teach however, the evidence is mixed (Wilson, 2008). In particular reference to school aged students, apart from a few arithmetic "tricks" that he performed he did not seem to have the spark. Also, he did not persevere in the school environment long enough to develop the skills, the total of his experience coming to less than a year.

Fit the Fourth: The Hunting (The language you speak)

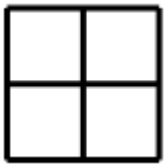
This Fit begins with the Bellman admonishing the Baker for not speaking his mind earlier. The Baker replies:

I said it in Hebrew – I said it in Dutch –
I said it in German and Greek:
But I wholly forgot (and it vexes me much)
That English is what you speak!

As teachers, and particularly teachers of mathematics, are we communicating the ideas in such a way that the students are catching what we are pitching? If not, then it is the same as speaking to them in another language. When a concept is new to us as teachers, or when we have not sufficiently explored its depths, we tend to communicate it to others in very narrow and restrictive terms. A complaint I have heard often from students over the years is that when they say to their teacher that they don't understand, the teacher often responds by repeating the same explanation in the same way as before. This can be an indication of the teacher only having one way of perceiving the material themselves. Marvin Minsky, one of the founders of artificial intelligence research, once said that "you don't understand anything until you learn it more than one way". What students are asking for when they admit their own lack of understanding is for another way to learn the idea.

The physicist Ernest Rutherford came to a similar conclusion after a series of conversations with a journalist in the 1930s. He is later supposed to have said that "if a scientist cannot explain to the woman who is scrubbing the laboratory floor what he is doing, he does not *know* what he is doing." (New Scientist, 1987)

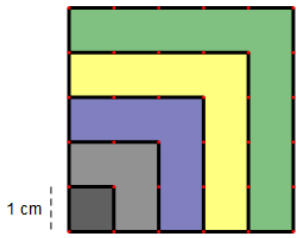
To illustrate the point from personal experience I recently was engaged in writing an activity on irrational numbers for year 8 students. I had been taught the concepts using variations on Pythagoras' Theorem and the number line. Neither of these approaches is suited to Year 8 in the Australian Curriculum so I developed an approach for looking at the size of squares that fit inside larger squares that are "perfect" in their length.

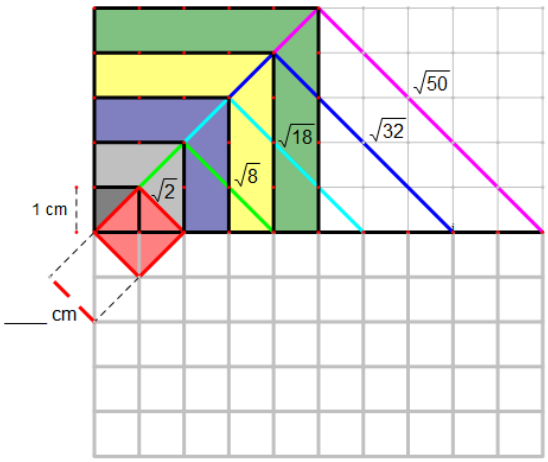


For example, what size square fits symmetrically inside a square of area 4?

The answer is a square of area 2. We can verify this result either by folding or cutting quite easily. To show that the value of $\sqrt{2}$ continues on indefinitely as a decimal, it is a simple matter of drawing the parent square with ever larger units: 4 cm, 4 dm, 4 rubber chickens, 4 m, etc.

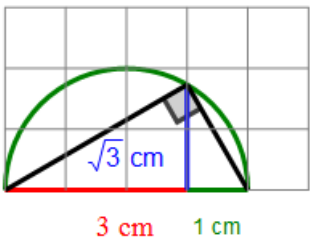
Given that this is true, and that the connection between the area of a square and the length of its sides is area equals length squared, we have found by manipulation a length of square root 2. This concept can be extended using diagrams like the ones below. (Picciotto and O'Connor, 2014)





In exploring further I then came across a lovely little example for geometrically finding the square root of any number using circles. (University of Wisconsin, webpage, 2011)

1) Choose a number to find the square root of, for example, 3.
2) Add 1 to get the diameter of the semicircle, D = 3 + 1 = 4.
3) Use a ruler to draw the diameter and a compass to draw the semicircle, as shown.
4) Divide the diameter into two parts, one part equal to 1 cm and the other equal to the length you want to find the square root of.
5) From the point you have just found, draw a vertical line up to the edge of the semicircle. The resulting length is the square root, in this case $\sqrt{3}$ or approximately 1.73 cm.

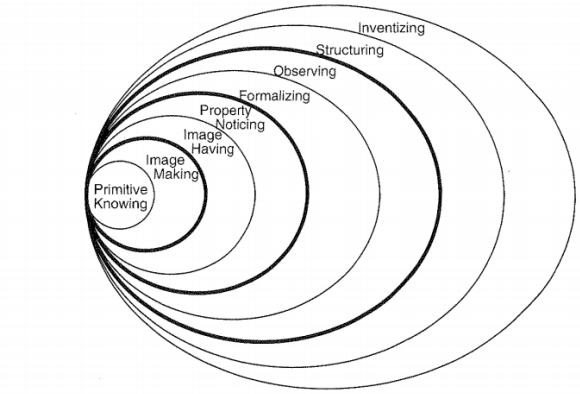


The advantage of both of these approaches is that there is no need to invoke the use of Pythagoras, they are simple, elegant and much more accessible to a wide range of student abilities.

Developing Understanding

Understanding of mathematical concepts is not a fixed or static quantity. Like Carroll's response to the meaning of *The Snark* each concept holds within it much more meaning than we originally perceive or intend.

In order to assist our students in gaining understanding we, as teachers, need to know how understanding develops. Pirie and Kieren (1989) envisage it as a series of ever expanding layers where continually more awareness of the object or concept are perceived. They also see the development of understanding as being a recursive process, with the learner moving in and out of the levels in both directions.

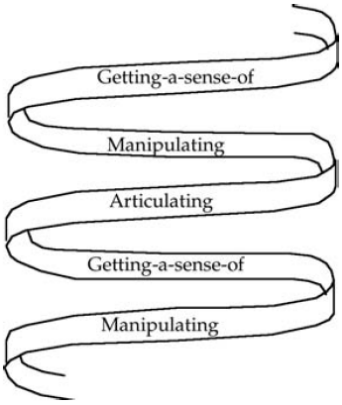


Mason et al (2005) describe the development of understanding in terms of a spiral with three distinct phases in each revolution:

Manipulating – either physical or in the imagination

Getting a sense of – recognising the "feel" of the idea being studied

Articulating – bringing the perceptual sense to a conscious level. This acts to clarify the idea, to give is solid form. This in turn creates a completely new "object" echoing Gopnik's (Carroll, 2006) assertion that "we live in a world not of our making that our imaginations help to make".



Many of the materials developed by AMSI over the years are designed to assist in the development of understanding by teachers and students. Of particular value are the Audit Documents and Module materials that are freely available on the Schools Division website: www.calculate.org.au

Fit the Fifth: The (Busy) Beaver's Lesson (The teacher-student relationship)

It is often the case that students and teachers start out as adversaries or antagonists, much like the Butcher and the Beaver did. After finding or establishing a common plan or goal though, the barriers come down and an openness to learning replaces it. This is one reason why many educators advocate the finding of a problem to be solved as a means to assist in learning. Indeed, with the Australian Curriculum, and its state-based variants, Problem Solving is one of the four Proficiency Strands that has replaced the older Thinking (or Working) Mathematically focus of the last couple of decades. In the work that the AMSI Schools division has done around the country in aiding teachers in implementing the new curriculum there has been a distinct progression in what teachers have asked for. In the first year or two the emphasis was almost solely on the Content strands, what is the same, what is different, what has been moved and to where. After this there is a gradual unpacking of the four proficiencies that we are seeing at the current time.

This movement towards codifying the capabilities embodied in the successful use of mathematics is an international one. Indeed, the four proficiencies in the current curriculum draw on a report in the United States entitled "Adding it Up" by Kilpatrick et al in 2001. (See Sullivan, 2012). The titles given to the proficiencies were slightly different but the descriptions remain the same.

It is both pertinent and instructive at the present time for teachers to see in their entirety what the definitions of the proficiencies actually are. It is for this reason that they are reproduced below. The bracketed terms relate to the Kilpatrick versions and are included for added depth.

(Conceptual) Understanding

Students build a robust knowledge of adaptable and transferable mathematical concepts. They make connections between related concepts and progressively apply the familiar to develop new ideas. They develop an understanding of the relationship between the 'why' and the 'how' of mathematics. Students build understanding when they connect related ideas, when they represent concepts in different ways, when they identify commonalities and differences between aspects of content, when they describe their thinking mathematically and when they interpret mathematical information.

Learn concepts, not methods.

A good mind devises its own methods
- anon

(Procedural) Fluency

Students develop skills in choosing appropriate procedures, carrying out procedures flexibly, accurately, efficiently and appropriately, and recalling factual knowledge and concepts readily. Students are fluent when they calculate answers efficiently, when they recognise robust ways of answering questions, when they choose appropriate methods and approximations, when they recall definitions and regularly use facts, and when they can manipulate expressions and equations to find solutions.

Problem Solving (Strategic Competence)

Students develop the ability to make choices, interpret, formulate, model and investigate problem situations, and communicate solutions effectively. Students formulate and solve problems when they use mathematics to represent unfamiliar or meaningful situations, when they design investigations and plan their approaches, when they apply their existing strategies to seek solutions, and when they verify that their answers are reasonable.

(Adaptive) Reasoning

Students develop an increasingly sophisticated capacity for logical thought and actions, such as analysing, proving, evaluating, explaining, inferring, justifying and generalising. Students are reasoning mathematically when they explain their thinking, when they deduce and justify strategies used and conclusions reached, when they adapt the known to the unknown, when they transfer learning from one context to another, when they prove that something is true or false and when they compare and contrast related ideas and explain their choices.

From ACARA (2011).

As we Butchers endeavour to assist our Beavers with their lessons we need to incorporate the how as well as the what and explain it all the while *in a popular style, which the Beaver*(s can) *well understand.* Success will take two forms: teachers and students will develop friendly relationships and students will be able to confess that they have *learned more in ten minutes* (from discussion with teachers) *than all books would have taught* them *in seventy years.*

Problem Solving Strategies

Of the four proficiencies it is Problem Solving that teachers most want assistance with in developing; whether with the design of appropriate or authentic tasks or with the way of implementing it in a classroom setting. On discussion with many teachers on this point it is frequently the case that they are not making use of Polya's Problem Solving Principles (1945). These principles are made up of just four steps, and the second, Devising a Plan, incorporates a list of strategies to apply. The principles and a partial strategy list are provided below.

1. Understand the problem
2. Devise a plan
3. Carry out the plan
4. Look back

Partial Strategy Checklist

Guess and check	Look for a pattern
Make a list	Draw a picture
Eliminate possibilities	Solve a simpler problem
Use symmetry	Use a model
Consider special cases	Work backwards
Use direct reasoning	Use a formula
Solve an equation	

Interestingly, I had occasion to have lunch with and then listen to Conrad Wolfram, the co-founder of Mathematica and Wolfram Alpha, in July of this year when he visited Melbourne. In part of his lecture he described what he saw as the Stages of Doing Mathematics. Like Polya, there were four components:

1) Define the questions
2) Translate into Maths (convert the real world into mathematics)
3) Compute Answers
4) Interpret Results (convert the mathematical solutions back into real world answers)

Wolfram and many other very successful entrepreneurs take the view that mathematical capability is vitally important for the modern world. This view is not a recent one either. While, as both the Bellman and Nelson said that *England expects* … "every man will do his duty" it was Nelson's adversary Napoleon who is quoted as saying "the advancement and perfection of mathematics are intimately connected with the prosperity of the State".

(Wolfram's most recent endeavour, the Wolfram Demonstrations Project is well worth investigating for more ideas on how to cultivate the Spark in school aged students.)

The Subject of the Beaver's Lesson

Before concluding this Fit it would be remiss if we did not make mention of the actual arithmetic problem that the Butcher showed the Beaver how to solve. It translates into mathematics as the expression:

$$\frac{(x+7+10)(1000-8)}{992}-17$$

With a little bit of observation and thought, each of the numerical elements eliminate each other leaving us with just x, and x is set at the outset of the problem as having a value of 3, which is the solution to the problem that was at hand. It is, then, a variation on several popular "mind reading" tricks often used by teachers to intrigue and engage their students.

Fit the Sixth: The Barrister's Dream (Do not defend the indefensible)

In contrast to the experience of the Beaver and the Butcher in Fit 5, The Barrister's Dream exemplifies much that tends to disengage and alienate students from the learning process. The Snark speaks for an interminably long period of time. When it comes time for the jury (class) to speak they do so all at once without pause or attention to others. The Snark defends, prosecutes, judges and pronounces sentence on a defendant who is incapable of being defended because it is already dead.

Teachers, schools, even educational consultants can be guilty of defending theories and techniques that the evidence does not support. In order to improve the learning outcomes of students it is sometimes necessary to let go of ideas and practices we have used, and in some cases held dear, for many years. If an approach doesn't work, or if it doesn't work well enough, then why keep doing it? Hattie (2009) provided an exhaustive catalogue of teaching approaches and schemes and their relative effectiveness. In linking these to Effect Size he also was able to go quite a way toward answering the question of "what works best" for learning. Hattie does not shrink from being controversial at times. What he seeks to do, it seems, is provoke debate that will lead to critical assessment of what we do as teachers. If we as teachers are serious about providing the best possible opportunities for our students we need to participate in this debate and base our arguments and decisions on rigorous analysis. We also need to continue to review any new practices that we might adopt to make sure that they remain effective.

One approach worth discussing in some detail in the context of finding the spark is deliberate practice. This is practice focussed on producing improvement. This often works best with two people where one is the learner and the other is a trainer, coach or mentor. The mentor's roles are to observe, identify weaknesses or flaws in technique or understanding, to diagnose the cause(s) of the difficulty, to break down the solution into parts, and then provide instruction around improving each of the steps. The role of the learner is to be attentive to the instruction and to engage with it along the lines of Mason's MGA spiral mentioned in Fit 4.

This approach also works at whole school levels. The Understanding by Design (Wiggins & McTighe) approach to curriculum planning is guided practice for teachers that can lead to improved outcomes for students if and where teachers deliberately and consciously consider each of the phases involved rather than just producing another written, and static, document to be dusted off every half decade or so when the next review comes around.

The whole school collaborative approach is yet another component of the AMSI Schools programs. AMSI specialists work with teachers in unpacking the curriculum, designing it to fit the uniqueness of each school environment while at the same time remaining faithful to the spirit of the curriculum.

Einstein is attributed with saying that "insanity is doing the same thing over and over again but expecting different results." If we truly want to change the results we are receiving we need to honestly, earnestly and deliberately work on changes to what we practice.

Fit the Seventh: The Banker's Fate (Learn from others even while you teach)

In this Fit, Carroll describes what can happen when only the observable actions of good practice are copied to the exclusion of the reasons why they are done and how. The Banker observes that the Baker has courage and, so inspired, rushes madly ahead only to meet with a most gruesome fate. His zeal has the effect of turning him into a negative of what he thought he was accomplishing. The Banker is an example of one who cherry picks parts of the solution, and focusses on this to the exclusion of the rest. It is also suggestive of holding individuals to a standard of expertise that they may not have.

Teachers traditionally have been expected to work alone in classrooms. It can sometimes reach the point where teachers feel that it is an invasion of their rights to have another professional observe and offer feedback. Teachers can increasingly feel isolated and incapable of seeking the assistance they require. This in turn can lead to a stiffening of approaches and techniques and an adherence to procedure over all else.

In contrast to this, schools and departments where there is an openness to sharing ideas, resources and teaching techniques deliver better outcomes for their students. The students in a school are not "my" students but "our" students and each individual teacher is entrusted with handing them on the following year as best prepared as possible. Despite the "Hollywood" stories even the best teacher in the world cannot produce exceptional results if they have to fill in holes left from earlier years.

Developing Deep Understanding

It is important for individual teacher development to create our own notes and to write our own assessment materials rather than just borrowing from other people. Text books and Black Line Masters are static documents unless or until the teacher using them has a sense of how they were put together, what the links between ideas are and why they are important. By engaging with the subject matter and turning it over in our minds, looking at it from different perspectives, always being open to discovering new properties we become better equipped to lead our students into that same place of "aha" moments and gratification.

A wonderful thing happens when teachers take this pathway for teaching. Eventually they feel confident enough to move away from the structure of the text and create bespoke or made to order, answers to student queries. The subject becomes a meaningful whole full of pattern and beauty yet free from restrained order. The spark catches hold, a light is struck and learning becomes an illuminated and illuminating process. This becomes infectious. Teachers pass it on to their students and can fan it into a flame. This has certainly been my experience and that of other teachers whom I consider to be highly effective in the classroom.

Fit the Eighth: The Vanishing (of Teachers from the profession)

This last chapter of Carroll's story ends, sadly, with the Baker vanishing without a trace. Why? And in the allegorical sense of this essay, why do teachers continue to vanish from our classrooms?

He, the Baker, was separated from the rest of his company. Likewise, teaching, in its day to day form, can be a very solitary profession. Mathematics teaching perhaps even more so than other subject disciplines. It is necessary to continually counter this and provide support to one another. It is interesting to contrast mathematics teaching in schools with the university environment where the tradition of taking tea is an integral part of the learning process, amongst the academics, not the students!

The faculty tea room of many universities is where academics gather to discuss ideas, seek help and collaborate with their peers. With the advent of the internet this has recently been taken to a whole new level. Similar to "citizen science" websites where professional paid scientists enlist the help of laypeople around the world there are also collaborative efforts in mathematics. Perhaps the most notable of these is the PolyMath Project. Australia's own Fields Medallist Terry Tao is one of the driving forces behind many of the projects hosted on the site. Mathematics in the real world is a collaborative exercise, a meeting of minds and ideas where sparks fly and new ideas are born. This is all too often missing in school classrooms.

To be sure, there are many other reasons for why teachers leave the profession but if more were to be able to capture the spark and develop ways of passing it on effectively to their students I expect that the rate of decline would be greatly reduced.

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