Contents

Introduction

What do we know about the science of expertise? It is expected that mechanics understand every part of a car and how it all works together. Chefs must know each ingredient and the best cooking techniques. Architects must know every angle and surface. Yet, as "architects of the intellect", do we educators have a deep understanding of how expertise is developed? Can we align our daily work most appropriately with the process of developing expertise and excellence? Ultimately, a primary goal of teaching is to build and foster expertise and the desire for it in our students. Despite this noble goal, however, we cannot always be aware of recent research advances in this emerging field of how expertise is developed.

THE PURPOSE

The purpose of this work is to look at the research on world-class performance, with the particular goal of distilling it for educators and applying it in classrooms. Armed with the insights this research can offer, educators will be on the brink of new achievements.

The first step is to fully realise the breadth of potential that exists. As Ericsson and colleagues emphasise, we need to "forget the folklore about genius that makes many people think they cannot take a scientific approach to developing expertise" (Ericsson, Prietula & Cokely, 2007, p. 116). Teachers can promote expertise systematically and consistently, and research documents this. Because of the importance of the science of expertise, it seems prudent for all stakeholders in the educational arena – school leaders, teachers and students who are on the brink of greatness – to know the true story of expertise.

World-class performance is the subject of many stories. It makes for great fiction. "Popular lore is full of stories about unknown athletes, writers and artists who become famous overnight, seemingly because of innate talent – they're 'naturals' people say" (Ericsson, Prietula & Cokely, 2007, p. 119). The problem is that the way greatness is depicted is most often completely fictitious. Hollywood fuels the idea of individuals who are "naturals", but the science tells us this is not the case.

The study of how expertise develops it not new. One of the first writers to explore the topic was English aristocrat Sir Francis Galton, whose major works were published first in the mid-19th century and, amazingly, remain in print today. Though his name may not be familiar, we immediately recognise a phrase he coined: "nature versus nurture". In fact, Galton's views on expertise represented a struggle between these two influences. As a young man, Galton believed that people were born with roughly the same capacities, which then may, or may not, be developed over life, and that a great portion of human potential was untapped.

However, Galton changed his perspective on things when he read the writings of his eminently famous cousin, Charles Darwin. Swayed by the case for heredity and natural selection, Galton (1869/2006) later wrote, "I have no patience with the hypothesis … that babies are born pretty much alike, and that the sole agencies in creating differences between boy and boy, man and man, are steady application and moral effort" (p. 56).

Yet within his view that heredity was very much dominant, Galton (1869/2006) did indirectly acknowledge additional factors in that his concept of natural ability contains three parts. One is clearly genetic. He refers to this as "capacity". But he also acknowledges that "eminence" is the result of capacity, "zeal" and "an adequate power of doing great work" (p. 39). Galton's works on the subject of expertise remained dominant until quite recently. This is witnessed by their continued publication and the continued discussions of "giftedness", which Galton began.

According to statistician David Banks (1997), if we view talent and expertise as natural occurrences randomly distributed throughout the world – as Galton did – then there is a "problem of excess genius". He asserted that "the most important question we can ask of historians is, 'Why are some periods and places so astonishingly more productive than the rest?'" In particular, he notes the following three places and times as ones of inexplicable genius, using historical views on innate ability: (1) Athens, from about 440 B.C.E. to 380 B.C.E.; (2) Florence, from about 1440 to 1490; and (3) London, from about 1570 to 1640. At the times listed, Athens was the pinnacle of the achievements in Ancient Greece; Florence was the epicentre of the Italian Renaissance, and the English literary scene of London included Shakespeare, Milton, Bacon and Donne.

Banks (1997) feels that "it is intellectually embarrassing that [the question of why some periods are so astonishingly productive] is almost never posed squarely, although its answer would have thrilling implications for education, politics, science and art." This answer to this essential question is at the core of research on expertise.

10 000 HOURS

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The modern exploration of expertise consistently traces back to the work of Anders Ericsson and his colleagues. Far from Galton's heredity-based view, modern authors in the field proclaim, "Consistently and overwhelmingly, the evidence showed that experts are always made, not born" (Ericsson, Prietula & Cokely, 2007, p. 116). After a substantial period of time in scholarly journals, the work of Ericsson and his colleagues began to make it to the mainstream in works like *Outliers*, with Gladwell's (2008) simplified interpretation of Ericsson's studies, for which Gladwell coined the phrase "The 10 000 Hour Rule." Additional works drawing from the research base include *Talent Is Overrated* (Colvin, 2008) and *The Talent Code* (Coyle, 2009). Yet, with the exception of Lemov et al.'s (2012) exploration of practice in *Practice Perfect: 42 Rules for Getting Better at Getting Better*, no one has yet fully explored the direct implications of this research for educators.

One possible reason why educators have not seen immediate implications for this research is that many works have taken a case study approach, profiling individuals. This made generalising their findings for broad application within schools difficult. Within the body of works on expertise, Dan Coyle took a very different approach, one much closer to schools. Instead of studying individuals, in *The Talent Code* Coyle (2009) chose to study "hotbeds of talent": towns, schools and even entire countries, current or historical, that have consistently produced a wildly disproportionate number of highly talented individuals. Banks (1997) might call these "concentrations of excess genius".

Coyle's (2009) work asks, how does one explain the dominance of the Brontë sisters within Victorian literature? Charlotte, Emily and Anne were successful authors. Any family would be happy having one child achieve literary success. The Brontës got three! Similarly, a tiny shopping centre vocal school has had its students go on to sign millions of dollars in recording contracts, and a seemingly modest music school in the Adirondacks lists among its former students some of the greatest living string instrumentalists: Itzhak Perlman, Yo-Yo Ma and Joshua Bell. Saying that there must be "something in the water" is not scientifically adequate to explain this success. Determining what these places do differently illuminates the talent code, which Coyle (2009) says contains three elements: deep practice, ignition and master coaching.

Ultimately, research consistently shows that our potential is not predestined or determined by our genes. "Talent is not a possession. It's a construction project and [educators] are the foremen" (Coyle, personal communication, 2011). As foremen of this critical process, we need to better understand its elements and procedures.

Forget Everything You Know

To dismiss what one thinks about expertise, down to the genetic level, involves changing deeply held beliefs. If we are to apply these new understandings about the science of expertise in our schools, two major thought changes must occur. First, we must dispel the myth of gene-based, predestined talent. Then, we must understand how talent develops through physiological changes in our brains.

Because of the widely held beliefs that talent and expertise are a result of genetic predisposition, a rethinking of some genetic basics is warranted. For most of us, the story of genetics began with the pea plant–growing Augustinian friar, Gregor Mendel, who pioneered study in this area. Armed with knowledge of dominant and recessive traits, we followed Mendel's lead, dutifully filling in our Punnet squares, applying what we thought was precise science to determine predictable genetic outcomes.

What we now know is that genes are far more complex and defy the simple logic of Punnet squares, which cannot always explain genetic outcomes. The problem with our Mendelian/Punnet Square–based perspective on genetics, where dominant and recessive determine outcomes, is that it only applies – and then not always – to a limited number of features. It doesn't take into account the fact that "genes are constantly activated and deactivated by environmental stimuli, nutrition, hormones, nerve impulses and other genes" meaning that "the exact same gene can produce different [outcomes] depending on how and when it is activated" (Shenk, 2011, pp. 22, 24).

Admittedly, "there are many elementary physical traits like eye, hair and skin colour where the process is near Mendelian – where certain genes produce predictable outcomes most of the time," but "the more complex the trait, the farther any one gene is from direct[ly] impacting the eventual outcome" (Shenk, 2011, pp. 24, 26). Given that manifestations of talent and expertise are incredibly complex, attempting to predict the outcomes using extremely basic approaches is futile. We need a new model.

GxE Mindset

Ultimately, experts in the field suggest that we abandon our "nature versus nurture" and reference "genes plus environment" (G + E) perspectives in favour of a "G × E" mindset, which attempts to capture the dynamic interaction (×) between genes (G) and the environment (E) where neither holds the trump card in determining how things will unfold. Synonymous with this is the concept of "dynamic development". According to Shenk (2011), "Dynamic development is the new paradigm for talent, lifestyle and well-being. It is how genes influence everything but strictly determine very little" (p. 33).

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The physical manifestation of dynamic development is seen in William Walter Greulich's 1957 study comparing the height of Japanese children raised in California, USA with those raised in Japan. With the similarity of a nearly identical gene pool and the environmental differences of better nutrition and medical care in California at the time, the California-raised children were an amazing 12 centimetres taller than their Japanese homeland counterparts. Clearly, environment has a substantial impact.

The second modern understanding about how talent and expertise are developed relates to physiological changes in our brains that we are just now beginning to fully understand. While many of us are familiar with the quintessential black cabs of London, few of us realise the intense, multi-year, and brain-altering process that is required to earn the cabbie license and ultimately pass a rigorous test referred to as "The Knowledge", which covers all of London's streets and major sites. The process, according to Rosen (2014) "has been called the hardest test, of any kind, in the world. Its rigours have been likened to those required to earn a degree in law or medicine. It is without question a unique intellectual, psychological and physical ordeal, demanding unnumbered thousands of hours of immersive study, as would-be cabbies undertake the task of committing to memory the entirety of London, and demonstrating that mastery through a progressively more difficult sequence of oral examinations – a process which, on average, takes four years to complete."

Before and after studies have documented that at the end of the arduous process, the newly certified "London taxi drivers had more grey matter [in areas of their brain related to spatial understanding] than people who were similar in age, education and intelligence, but who did not drive taxis" and "the longer someone had been driving a taxi, the larger his hippocampus, as though the brain expanded to accommodate the cognitive demands of navigating London's streets" (Jabr, 2011). The hours of study and practice had literally changed their brains.

Myelin Matters

Numerous discussions of expertise reference extensive hours of deliberate practice, and we will address this, but among the earliest to discuss the results of practice from a physiological perspective was Dan Coyle in *The Talent Code,* when he explored new insights about myelin, a white substance that surrounds the axons of some nerve cells. Coyle points out that while knowledge of myelin is not new to us, it was historically viewed as far more inert then we now understand it to be.

In the early years of brain-based learning, "neurons and synapses [got] the lion's share of research attention" (Coyle, 2009, p. 40). University of Illinois professor Bill Greenough remarked, "We'd been ignoring myelin; then, around 2000, new imaging technologies gave us the capacity to explore myelin like never before, and the findings were staggering. In study after study across multiple fields of expertise, the correlations between myelin and ability were unquestionable" (Greenough as quoted in Coyle, 2009, p. 29).

As Coyle (2009) notes, myelin provides us "a vivid new model" for understanding talent because how it grows is no longer a mystery: It grows through practice or repetition. Research done by Dr R. Douglas Fields (National Institutes of Health) and others on how myelin grows is summarised by Coyle (2009) as follows:

> The more the nerve fires, the more myelin wraps around it. The more myelin wraps around it, the faster the signals travel, increasing velocities up to one hundred times over signals sent through an uninsulated fibre. (p. 40)

Metaphorically speaking, "Myelin quietly transforms narrow alleys into broad, lightning-fast super-highways" (Coyle, 2009, pp. 40–41). The increased transmission speed of a highly myelinated neural circuit coupled with the reduced "refractory time (wait time required between one signal and the next)" which also develops, "boost overall information-processing capability by 3000 times" in contrast with an un-myelinated pathway (Coyle, 2009, p. 41). So, Serena Williams executes functions related to tennis with far more efficiency and precision than someone first picking up a tennis racket because the neural pathways of her brain have been altered substantially by practice. Yo-Yo Ma masterfully draws a bow across a cello's strings with precision unmatched by any novice cellist because practice has rewired his brain to be able to do so.

In short, genes do not predetermine talent and the development of expertise. From a physiological perspective it is really the building up of myelin through sustained practice, a process that literally changes our brains and increases our abilities exponentially.

So, if expertise is physiologically within most everyone's capacity, why do so few reach appreciable heights? To fully understand this, Coyle's talent code elements are useful. Beyond the myelin-building deep or deliberate practice, considerations of ignition or motivation are needed, as well as the input of a master coach. Without a motivational drive, doing the necessary deliberate practice is nearly impossible, and without a master coach to guide and inform the process, it is likely that practice will not be appropriately directed to extraordinary levels of excellence and expertise.

Our Journey

In this book, we will begin by exploring ignition or motivation, which can take two forms. One form of motivation is the slow stoking-of-the-fire kind, which we will consider in Part III. But sometimes ignition is a "big bang" of energy. It's the explosive moment when a student is so inspired by a performance that she decides that she would like to learn a specific skill or develop a specific ability. This is the focus of Part I.

We will then transition to exploring deliberate practice, which is the actual stuff of expertise making. We have the potential to become experts, but only through deliberate practice. Thus in Part II we will juxtapose deliberate practice with what most of us do when we merely practice, and discuss how we can bring more deliberate practice to our classrooms. To be clear, it is through deliberate practice that experts are made, but the quantity and rigours of such practice require us to also thoroughly explore motivation. As Barr (2012) puts it, most often "motivation becomes the real constraint on expertise".

In Part III we will turn our attention to master teaching or coaching for expertise. In this section, we will also be exploring the other form of ignition, the slow stoking-of-the-fire kind, which is so essential due to the thousands of hours of deliberate practice necessary for eminence.

The Mission

Teaching for expertise might seem daunting to some F–12 educators who possibly view their role as generalists, but studies clearly show that expertise traces back to early beginnings – the first time one ever touches a piano, picks up a paintbrush or first makes sense of letters or numbers. The mission is clear. If educators want to take students to higher levels, if we are to prepare