Mathematical minds

Kate Smith-Miles[1]

Gazette: Your undergraduate degree is a B.Sc. (Hons) in Mathematics. When did your interest in mathematics begin, and how did this lead to your choice of undergraduate study?

Smith-Miles: Like most mathematicians, I loved maths in high school. I had an inspiring maths teacher and by the end of Year 12 I wanted to learn more maths. I didn't know what a mathematician did, but I couldn't imagine anything I could do as a job that would be more fun and rewarding than solving differential equations all day! Strangely, the teacher who had been so inspirational tried to dissuade me from studying maths, and thought that I shouldn't waste my marks doing a science degree. Having a father who is a doctor meant that I was most certainly not interested in studying medicine though. I had seen enough to know that you need to feel a calling to that kind of commitment and responsibility. I decided to follow what I was passionate about, and to continue learning more about mathematics.

From my very first lecture at the University of Melbourne I realised where my mathematics degree would take me — I immediately wanted to become a lecturer. The material we were being taught was so interesting, and yet it was being taught in the most boring way imaginable by someone who didn't seem to want to be teaching a large class of rowdy first years. Someone next to me told me that lecturers were paid over $100 per hour, which seemed like great recompense considering I was earning a living doing lots of $20 per hour private tutoring jobs. I already knew that I loved teaching, and combining teaching with time to solve my own maths problems suddenly seemed like the ideal profession for me. I asked the student next to me if he knew what you had to do to become a lecturer, and he said that I needed to get a PhD. So from day one I approached my undergraduate degree knowing that I was going to do a PhD and become an academic.

Gazette: What drew you to a PhD in Electrical Engineering?

Smith-Miles: I originally planned to do a PhD in mathematics, continuing my honours topic on chaotic dynamical systems with Colin Thompson. This was a topic that was introduced to me by Reinout Quispel when I did summer vacation work at Latrobe at the end of third year. But in the week that PhD applications had to be submitted, an engineering friend of mine told me that one of his professors was looking for a maths student to work on a PhD project in collaboration with CSIRO. It sounded fascinating when I went to meet with the professor (Marimuthu Palaniswami). He was proposing that I develop mathematical models of the human brain (systems of differential equations called artificial neural networks) to solve NP-hard combinatorial optimisation problems. The idea had been demonstrated

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already, but there was much scope for refinement and extending the concepts into new territory. Most attractive to me was the prospect of working with CSIRO to use the developed techniques to solve practical optimisation problems. I had a supervisor in the operations research group at CSIRO Division of Mathematics and Statistics (Mohan Krishnamoorthy) and spent every day at CSIRO. So even though technically my PhD is in electrical engineering, I didn't spend much time in the electrical engineering department at the University of Melbourne, and I really consider that my PhD is in applied mathematics.

Gazette: What was your career path from PhD to your current position as Head of the School of Mathematical Sciences at Monash University?

Smith-Miles: During the three years I spent at CSIRO completing my PhD I learned a lot about real-world problems, consulting work, and so forth but I also realised that this was not the ideal work environment for me, since I really love to teach. Towards the end of my PhD, I walked across the road to the mathematics department at Monash University and asked if they did operations research, but they told me that most of the operations research people at Monash were in the IT faculty. So I dropped in to meet the Head of the School of Business Systems who chatted to me for a while, took a look at the five journal papers I had written from my PhD, and offered me a lecturing position on the spot! I couldn't believe it. I had gone to see if they had any postdoc positions and wasn't expecting to be offered my dream job straight away. The position hadn't even been advertised. I don't know how they arranged it, but I started two months later in February 1996.

Over the next 10 years I was promoted regularly through the promotion committees until I reached full professor in 2006. During that time I had won about six ARC grants, supervised about 15 PhD students, been Director of Research and Deputy Head of School, and been Director of the Monash Data Mining Centre. My research had stayed mathematically focused, but had diversified to include data mining and pattern recognition, time series analysis, chaotic neural networks, as well as optimisation. My interest in practical applications had been useful during that time to develop many fruitful collaborations with colleagues across different faculties at Monash, including epidemiology, engineering, medicine, microbiology and finance, as well as industry collaborations. During that time I also became a mother to my two beautiful and talented children (Charlotte born in 2002 and Jamie born in 2005). It was certainly a busy 10-year period!

Once I reached full professor it felt like I had reached a point where I needed to decide to either continue doing more of the same or look for new challenges. My research was starting to feel too broad, and I started not to enjoy that aspect of my job. Sometimes when you spread yourself too thin you lose the rewards that come from making truly significant breakthroughs. Where I was feeling rewarded though was helping other people develop their research careers, and supporting them so they could make their breakthroughs — there was a gratitude from them that made it all seem worthwhile. Once I had my children it felt like there was not enough time in the week to do both: progress a deep research agenda of my

own while simultaneously supporting a full load of PhD students, numerous cross-disciplinary collaborations, and also support the research efforts of all staff in my school with grant reviewing and so on.

After some considerable thought I decided to apply for a Head of School position that had been advertised at Deakin University. It was clear from the outset that this was an ambitious role. The School was newly merged and comprised the disciplines of engineering, IT and mathematics. Given my multi-disciplinary background and recent leadership experience, the position description seemed to have been written for me! The main problem was that the school was not just disciplinarily spread, it was also geographically spread — half of the school was in the Melbourne and the other half in Geelong (a 90-minute drive away). After the first day in the job, when I went to the Geelong campus and returned late that night to find over 100 unread emails in my inbox, I knew that I would only be doing one three-year term as Head of School! My three years at Deakin were great, and I learned a lot about running a school. I also learned about the importance of mathematics service teaching, and enjoyed greatly the years I spent teaching mathematics to first-year Bachelor of Primary Education students.

At the beginning of the third year of my term as Head of School, I heard that Monash University had advertised for a Head of the School of Mathematical Sciences. The position description also seemed like it was written for me! So I applied, and was successful, and started the role in January 2009. It is a dream job for me: great staff, great students, great university, and 20 minutes from home! I finally feel like I am getting the balance right between work and family, and the balance right between making my own research breakthroughs and supporting others to achieve theirs.

Gazette: Is there a common thread that ties your research in different disciplines together? How has your research focus developed over time?

Smith-Miles: Interestingly, now I think about it, a common thread could be differential equations (more complex than the ones that inspired me in high school of course!). My neural network work is based on differential equation models of the brain, and some of the things I have been doing more recently in mathematical biology also involve differential equation models, such as modelling stem cell differentiation pathways. But I suspect I am working too hard to find a common thread — my research journey has not been constrained by a single common thread.

Soon after my PhD when I began working as a lecturer in the IT Faculty at Monash, I was advised to find a less-mathematical, more business kind of research direction. While I kept my chaotic dynamical systems interests alive with chaotic neural networks research, I conceded by also looking at other kinds of neural network models that were being used for business problems like stock market prediction. These methods learn patterns in data by experience, like humans do, by some mathematical algorithms that adapt, over time, the network structure to minimise errors in performance. A lot of the industry work I have done, and much of the inter-disciplinary work, has had learning as a common thread.

In recent years I have focused on applying the idea of learning patterns in datasets to my original research domain of combinatorial optimisation. The ability to learn is a critical ingredient of 'intelligence', and so this fairly new area of research is known as 'intelligent optimisation'. We build mathematical models to learn from the experience of solving many different instances of an optimisation problem, and try to gain genuine insight into the properties of the instances that make certain algorithms excel or fail. This insight can then be used to predict performance and eliminate tedious trial-and-error search for the best algorithm (or set of parameters for an algorithm), and can also assist the development of new algorithms better tailored to the properties of the problem.

Gazette: What has been a highlight of your career so far?

Smith-Miles: Winning the AustMS medal in 2010 is an obvious highlight. While I have received recognition from other disciplines for the contributions I have made to them (using mathematical techniques), it is even more valuable to me that the mathematics community considers that I have contributed significantly to mathematics as well. I was especially gratified by the committee's citation which described my contributions as 'characterised by their extraordinary breadth, as well as an exceptional attention to rigour'. These are precious words for an applied mathematician.

Gazette: What do you do to relax?

Smith-Miles: The fastest way for me to unwind is to play the 'cello for 10 minutes. My favourite piece at the moment is 'Oblivion' by Astor Piazzolla, which I then usually follow with something from one of the Bach 'cello suites. There is something about the rich resonance of the sound and the physicality of playing it that immediately makes me feel rejuvenated.

Music has always been a significant part of my life, and the relationship between maths and music is one that has fascinated me for years. I wrote an essay on the topic in Year 11 and developed some (unnecessarily complex) formulae to enable the key to be determined based on the number of sharps or flats (of course, musicians just memorise the 'circle of fifths' but I thought it was neat that a mathematical formula could be derived).

My first research experience was also on the relationship between maths and music: in third year Derek Chan supervised an undergraduate research project where I took the first note in each bar of the Bach First Invention in C major, performed a fractal interpolation, and generated a new piece of music. This was how my relationship with my husband started. When we met and I found out that he was a musician, I started telling him about my project and he said he would be really interested to hear the music that the fractal produced. He analysed it for me (it turns out to be in the Ancient Greek Phrygian mode rather than C major, which he thought was fascinating but I still don't know why 20 years later!), and one thing led to another. I've never thanked Derek Chan for choosing a project that changed my life, so thanks Derek if you read this! These days my interest in the relationship between maths and music is one that I explore not just with my husband, but also with our children, both of whom are talented little musicians.

I also play in the 'cello section of a local community orchestra when conference travel doesn't interfere, but I try not to talk to them about mathematics!

Kate Smith-Miles is a Professor and Head of the School of Mathematical Sciences at Monash University. Prior to this role, she held a Chair in Engineering at Deakin University (where she was Head of the School of Engineering and Information Technology from 2006 to 2008) and a Chair in Information Technology at Monash University (where she worked from 1996 to 2006). Kate has published two books on neural networks and data mining applications, and over 200 refereed journal and international conference papers in the areas of neural networks, combinatorial optimisation, intelligent systems and data mining. She has supervised 18 PhD students to completion, and has been awarded over AUD$1.75 million in competitive grants, including eight Australian Research Council grants and industry awards. She was awarded the Australian Mathematical Society Medal in 2010 for distinguished research.