Guest Editorial

One of the big advantages of becoming a mathematician as a second career is that you really remember what it is like to be a non-mathematician. This is a big advantage if you want to interact with non-mathematicians, whether that means people in other departments in your company or users of your academic research.

My motivation for this late entry into mathematics was to become a schoolteacher; my children were growing up and I did not want to go back into accountancy. Having been refused permission to take A-level maths at school (told I would 'never cope'[1]), my first port of call was my local college to fill that gap. When I arrived at university, mathematical modelling was part of the course. I was astonished to discover that we can use maths to make people's lives better! I had no idea! I can trace my journey into research back to that first term of undergraduate study.

There is clearly an appetite for mathematical modelling within industrial–academic collaborations. The European Study Groups with Industry (ESGI) goes back to 1968 and has a large number of industrial collaborations and problem reports to its credit. My own first taster was in 2010, when it came to Warwick during my PhD (ESGI73). I thoroughly enjoyed the 2nd UK Graduate Modelling Camp which preceded it, and our paper from that camp on 'Modelling a cadaver decomposition island to estimate time of death' remained my most-read paper on ResearchGate until it was surpassed by last years' offering on response of pollinator abundance to environmental pressures [1]. The Knowledge Transfer Network (KTN) study groups borrowed the same format as ESGI and then the Turing Data Study Groups followed suit. I have always found study groups an opportunity to think about things differently. The beauty of mathematics is that apparently different problems are mathematically similar and therefore can be approached in common ways. This is one of the most surprising aspects of mathematics for non-mathematicians, for whom the notion of 'similar' is different from ours. And it is also our point of difficulty.

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For people from the business, government and industry organisations who come to ESGI and the like, the connection between their problem and mathematics is, at least somewhat, understood. For many others, there is no concept that mathematics has any contribution to make at all. This came out particularly strongly at a recent meeting on the Industrial Strategy Challenge Fund (ISCF) and UK Mathematical Sciences, held at International Centre for Mathematical Sciences (ICMS) meeting in Edinburgh (see www.icms.org.uk/ICSFStrategic.php). There is a great deal of funding available for these industrial challenges, but the mathematical sciences have been largely conspicuous by their absence. Part of the reason is structural – applications require large consortia and timescales are short, so unless those relationships are already in place, it is hard to bid into those calls. Mathematicians do not, generally, work in very large collaborative groups, as shown by Kenna and Berche's [2] analysis of optimal group sizes for research quality (as defined by the Research Assessment Exercise (RAE) 2008 funding formula). They showed that optimal group size was smallest for pure mathematics and that applied mathematics was in the five smallest disciplines. Another challenge specific to the ISCF is that the wording of the calls do not immediately alert those in the mathematical sciences that they have a contribution to make. Both these problems were addressed at the meeting. First, time was given to examining challenges where the funding

Pollinators are a vital part of human and animal food chains. Mathematical modelling can help policymakers support pollinator abundance.

is not yet fully allocated, in Waves 1, 2 and 3. In discussing each challenge in turn, it was clear that the mathematical sciences had a great deal of potential to offer[2], notwithstanding John Cookson's warning against *Premature Mathematisation*[3]. After this, some thought was given to the kinds of wording that would attract mathematicians to a Wave 4 call.

Of course, the small research groups that optimise the mathematical sciences research quality are not the only contexts in which mathematicians operate. Typically, we have regular conferences, some of which are mathematically quite broad and some of us are also part of cross disciplinary groups. These help to provide the networks required to respond to challenge opportunities set by business, government and industry. One recent experience is that being part of the Analysis under Uncertainty for Decision Makers (AU4DM) network, allowed me to pull together a multidisciplinary team to respond to one challenge, conveyed via the Alan Turing Institute (ATI), which would otherwise have been impossible. In addition to a large number of mathematical scientists, this network contains experts in management science, psychology and structured expert judgement. Through the network, I was able to add members to my team with further expertise in digital humanities, graphic design and games concept design required to complete the project.

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This project was an example of co-creation[4] of research outputs, both with the industrial partner and across disciplines. There are a number of challenges associated with such interdisciplinary working. Interdisciplinarity, whether in teaching or research, is hard to define, but you know when you are doing it. It is a bit like crossing into a new country; the trees, grass, buildings and people may look familiar, but suddenly non-one understands a word you say. In interdisciplinary working, we are divided by subject-specific languages and by differing conventions. There is labour and humility required on all sides to dissect and understand those differences and negotiate a way forward together. Like all things, this becomes easier with practice, and it is possible to become bilingual or trilingual.

If the Bond review [3] recommendations are implemented, there should be support for this labour. Any Academy for the Mathematical Sciences should provide a one-stop-shop for business, government and industry to access the mathematical sciences community, similar to the ATI's growing reputation in the field of data science. In addition, the Bond review highlights the need for a pipeline of people, recommending that knowledge exchange and problem solving be incorporated into undergraduate, masters, PhD and postdoctoral training. There are a great many advantages to this for the individuals concerned, particularly in overcoming the experience barrier, learning communication skills[5] and widening employability opportunities. However, there are also hazards. In particular, qualifications need to be examined, and this requires them to sit within disciplines. Interdisciplinary PhD research can be hazardous for the candidate [4] since higher education structures are organised around and reward hyper-specialisation.

My own experience is in negotiating MSc projects with partners from business, government and industry. This first requires the potential partner to recognise the value of working with the mathematical sciences. My main weapon in this regard is the use of stories, selected to be relevant to the interests of the potential partner. It also helps that the research projects are both free (in cash terms) for the partner and short (so that in-kind contributions through co-supervision, etc. are limited). One of the frailties of working with partners is that they are typically reliant on a personal relationship established with an enthusiastic individual, who then needs to be supported to advocate for the relationship with his/her manager. When that individual moves to a new role, the relationship can be lost, so building a relationship to the point that it is independent of the individuals at both the business and university ends is important (but hard to do).

Of course, before you can tell the stories, you need an audience. My story-telling began during my undergraduate days with my friends and family, who could not really understand why a middle-aged mum would be pursuing mathematics. The mathematical modelling, that I found so inspiring, was an invaluable resource. Let's tell our stories to a whole range of audiences, whenever we have the chance – everyone needs to know how amazing mathematics is at delivering things they care about.

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Notes

1 This was neither the first nor last time I was told I would fail and I gave an exposition of my journey at the IMA Academic Representatives' Forum in January [5]. Since neither other people's opinions nor my own imposter syndrome has prevented actual achievement, I mention them only as an encouragement to others to persevere.

2 Should any reader wish to engage with the ISCF programme, they are encouraged to contact the relevant challenge lead or Matt Butchers at KTN for more information.

3 'Models with an inadequate evidential basis will be a complete waste of both mathematicians' and domain researchers' time …' [6].

4 This was the main message of Dietmar Hömberg's opening talk at the IMA's first Knowledge Exchange conference [7].

5 '… communication skills can be learnt' [8].

References

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2 Kenna, R. and Berche, B. (2012) Managing research quality: critical mass and optimal academic research group size, *IMA Journal of Management Mathematics*, vol. 23, pp. 195−207.

3 Bond, P. (2018) The era of mathematics; an independent review of knowledge exchange in the mathematics sciences, epsrc.ukri.org/newsevents/pubs/era-of-maths/ (accessed 1 April 2019).

4 Brabazon, T. (2019) Dean of graduate research, Flinders University, Vlog 157 Interdisciplinarity, www.youtube.com/watch?v=8edoQfdvNHg (accessed 1 April 2019).

5 Christian, J.M. (2019) Third Academic Representatives' Forum, *Mathematics Today*, vol. 55, no. 2, p. 47.

6 Cookson, J. (2018) Premature mathematisation, Letters, *Mathematics Today*, vol. 54, no. 6, p. 259.

7 Champneys, A. (2019) Knowledge exchange after the Bond review, *Mathematics Today*, vol. 55, no. 1, pp. 4–5.

8 Cody, J. (2018) Being and autistic engineer, *Mathematics Today,* vol. 54, no. 4, pp. 138–139.