Editorial

As the IMA looks back on 60 years, it seems a good time, as a mathematician, to ponder the impact of mathematics, but also to spare a thought for the risks it could pose.

Mathematics is fundamental to our understanding of the universe, it is the language of physics and general relativity. It has provided answers to the most fundamental human questions, helped develop incredible medical advancements, put the knowledge of the world into the hands of everyone with a phone, enabled us to send people to space and to communicate instantly. Without mathematics our modern world would simply not be possible. However, it is in its application to everyday life that mathematics becomes most powerful and it is critical that power is used correctly.

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On the About Us page of the IMA website you can find the following statement:

> The Institute of Mathematics and its Applications (IMA) exists to support the advancement of mathematical knowledge and its applications and to promote and enhance mathematical culture in the United Kingdom and elsewhere, for the public good.

It is interesting that the word culture is used here, but also that it is very clear everything we do has to have the public good right at the forefront. In some senses, at first glance, this isn't something a mathematician needs to worry about. In its purest form, mathematics is neither good nor bad, and when we are using it to understand the universe, it is simply a language that is used to communicate.

All of us have seen mathematics used to justify and evidence human decision making and it is here, at this crossover point, that there is challenge, because here mathematicians must account for uncertainty. Here, we who are fluent in this language and understand its power and beauty, as well as its limitations, have to propagate a culture in which mathematics is both questioned and respected in equal measure. In a country where 'I was never very good at maths at school' is a phrase that is commonplace and accepted, we need to facilitate complex discussions about the ethics of Artificial Intelligence and the finer points of future risk assessment and model dependence. We need to make sure mathematics is understood.

We are the only ones who can really facilitate a culture where it is normal to think critically about whether the statements we are hearing make mathematical sense, but also to respect that some mathematics is so complex there are a scarce few people in the world that will ever be qualified to review it. To do this, we have to not only understand and ensure that what we are doing is done to the highest standards, but also have the courage to say when mathematics doesn't or cannot provide the answer.

We have all seen the terrible impact when mathematics is not well understood, or used badly, and many of us have spoken out against this.[1] However, as mathematical models get more complex, what is right and wrong becomes harder and harder to assess.

To explain why I think this is a key issue I am going to use an example we, as a country, are well known for talking about – the weather. I am going to use the weather precisely because it does not have any particular emotional or political nuances, unlike many other areas like medicine or economics. I am therefore doing the first thing that many mathematicians are good at doing, I am simplifying the problem – hold that thought, I will come back to it.

Weather forecasting is difficult. The mathematical models that are built to predict weather are actually incredibly good, we are now able to predict further into the future, at smaller spatial scales and with more accuracy than ever before. We are capable of integrating real world observations in real time with our forecasts to improve our estimates, we can predict massive global scale phenomena and we can save lives doing so. Weather forecasting is critical for hurricane and flood warnings, for example, and our weather models and expert weather forecasters provide crucial, accurate information that really does make a difference. Yet, if I ask my friendly AI whether it is going to rain, it quite often gets it wrong. Now the implication of this unreliability to me is slight, I carry an umbrella unnecessarily or (more often) I get wet in the rain.

But my weather app still says there's a low chance of rain

However I, as a mathematician, understand the principles of mathematical modelling. I understand notions such as turbulence, multi-scale error propagation, random chance and some of the huge complexities of predicting exactly when and where moisture will turn to rain, even if the overall forecast is right. I understand that the mathematics is limited but still incredibly good. My worry is that not everyone shares this understanding. Instead our population is given hour by hour breakdowns of the percentage chance of rain and they look out of the window and see these predictions are very often wrong. So we now get back to culture.

If it is raining now, and I can see that out of the window, but the forecast says there is a 10% chance of rain then I know what that means. There was a predicted chance, but that was before the probability had been realised, the sample taken from the distribution. So why is the current forecast relevant? Is showing what it was adding any information? In a culture of fast, accurate answers, where our mathematical models are presented ever more widely and perceived to be wrong ever more often (even if they are actually right, there was after all a 10% chance of rain) how is this affecting people's trust in mathematical modelling. How do we maintain trust while fostering critical thinking?

I have used the weather as an example here, but the question holds far more generally, wherever mathematics underpins decisions.

Furthermore, if we know we have to simplify the problem in order to predict or model something, or we have to make a set of assumptions, how do we know we are actually helping to make the *right* decision? Lastly, because critical thinking is one of the gifts mathematics gives us, so I do it even when I don't want to, does it even matter?

I am afraid I don't have the answers, but I can offer some pointers and, maybe if I'm lucky, even start a conversation that improves them.

The decision matters

Mathematics will generally be used for something, even if you aren't sure what yet, make sure you consider this and are clearly stating the assumptions, limitations and simplifications.

Uncertainty matters

Outside of pure mathematics, the real world is uncertain, we make approximations and simplifications, and we must honestly and openly find a way to talk about uncertainty in a way people can understand.

The assumptions matter

If you are creating mathematics that only works given particular assumptions make sure these are really easy to understand and impossible to forget.

The scope and scale matters

So often people apply mathematical predictions at the wrong scope and scale. Just because I can predict the path of a storm does not mean I can predict its exact impact on a particular area (scale). Just because I can predict the path of a storm does not mean I can predict how people will react to that news (scope).

Does it actually matter anyway?

Now to that last question, does it actually matter anyway? Our discipline is the crucial underpinning of the modern world, we are the ones most fluent in it and I think it is incredibly important that we have a voice and we can help solve society's problems and focus on knowledge exchange will help us achieve that. You can disagree, I am also happy with that, this after all is an editorial, not a mathematical argument. But I also understand and respect that difference. If I state a fact ($1+1=2$ in base ten for example) there is no other opinion, it is therefore our role to help distinguish the difference. To help society with decisions based not only on factual mathematics, but also by interpreting those facts in light of uncertainty.

NASA Earth Observatory

Storm Ernesto heading towards Bermuda

So yes, I really think it does matter and I think we are at a point in time where mathematicians can make more of a difference than ever before. Let's make sure it's a good difference and that people understand the difference it can (and can't) make.

Let's make sure the next 60 years continues to deliver the huge impacts we have seen mathematics deliver in the last 60 years and moves as far away from the post-evidence era as we can get.

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Notes

1 For instance the distressing case of Sally Clark (www.bmj.com/content/320/7226/2) or the financial crisis of 2008–2009.