RSC 3: WHY PUBLISH RESEARCH….AND WHY IS THIS SO HARD IN OUR FIELD?!

There are few topics that stir so many emotions and controversies as publication. With publications we normally refer to peer-reviewed journal papers that traditionally were printed, now online or open-access publications are common. Publication involves writing up results on a certain research topic, presenting it in light of the literature, emphasizing the novelty and new knowledge gained. It is naturally a lot of hard work.

Typically, engineers have published less, years ago many engineering academics did not even have PhDs. The field used to be more focused on problem solving for industry, patents and know-how, consulting, designing and building things. Naturally engineers do not tend to choose this profession because they are geniuses in language and writing, but rather creative hands-on people. This means writing is often neither a natural skill, nor a prime motivation. Consequently, the need for scientific reading and writing poses a challenge, long before the relentless revisions, polishing and responses to sometimes tough or even (perceived) offensive peer review comments.

Publications and citations are key performance indicators. Some institutions use this as the main selection criteria while others fiercely defend that publications do not matter. Both extremes are unhealthy, on the one hand too much nonsense is published and on the other an avoidance of the inevitably hard writing work withholds knowledge. There is a need to design and build useful things, make the creations work and then write and tell others about it. Researchers have different skills and may need to put a bigger effort into what does not come naturally, to achieve a good balance between quality and quantity, and valuing technical skills. This makes publication in engineering excruciatingly difficult, yet incredibly important!

Personally, I was trained in the Australian 'publish or perish' environment. H-index and field specific standardized citation indicators quantify citations. When working in the UK stated clearly that a researcher is only as good as their last 2-3 papers, indicating a need for continuity and increase in quality. In some countries, a *Nature* (or *Science*) paper is required to achieve appointment or promotion, and this is especially hard in engineering, while encouraging (albeit not justifying) a lot of very unacceptable side effects appearing from shortcuts of all sorts, data faking through to corrupt authorship practices. The purpose of publication is not to gain a PhD or to be promoted. So why do we need to publish at all?

In my opinion a few concepts are key that are integral to our duties as academics and researchers;

- **RESEARCH LEARNING:** inarguably teaching young researchers is our core duty. This means, compared to coursework, lab work and pretty individual and time intensive supervision. Part of this learning, other than doing experiments, is to learn to plan and structure research, set up equipment, formulate research questions, analyze and present data, validate and interpret results, understand and explain things that noone has seen before. This means writing up results, critical enquiry, scientific debate (or even arguments) is part of the journey and there is no better way to engage in this process than the preparation of a scientific manuscript that will be (if you are lucky) scrutinized by a leader in the field. There is not a lot worse than evaluating a PhD where the data has not been through this process and a university administration wants an answer to the question '*Is the work would be publishable in principle?*'. The much better question would '*was it published in a well-respected journal?*' Learning is a lot of effort and writing a good paper is hard, but writing is part of the research process and writing helps structure the research well. The best guidance occurs through a supervisor who cares enough to give thorough feedback, which takes a lot of time.

  'Writing is part of the research process'
  (George Whitesides)

  The fact that publication is a learning process means that not all publications can be high impact or perfect. But there are clear guidelines for data integrity and truth. Needing to publish to get a PhD is no excuse to not validate the data – or go back and correct mistakes. Failures are part of learning.

- **KNOWLEDGE COMMUNICATION:** A second core duty of a researcher is the generation of new knowledge that will contribute to our body of knowledge. This requires that this new knowledge is made available and this means it needs to be communicated such that it makes sense. This also means that one cannot simply upload datasets for public use, the context and the conditions in which the data was generated typically matter and this needs to be explained in a publication to avoid misinterpretation and ascertain

reproducibility. Knowledge in individual expert heads and locked drawers is not available to others and hence cannot contribute to solving global problems. The experience of brilliant engineers – designers or operators - is often lost when the person retires. This means others have to try and acquire this experience in a painful manner all over. While this may signify a competitive advantage in private business or geopolitical competition, when it comes to solving global environmental and public health challenges a more cooperative approach is beneficial. This of your legacy and actual contribution your work can make. In knowledge communication one needs to question what communication is worthwhile. Overall, there is now a flood of communication, fake news, irreproducible data, self-perpetuating hypes, and utter nonsense – this will probably not improve through the generation of publications with artificial intelligence. This leaves us often questioning if what was reported is true. This requires a good grain of critical and responsible self- and peer- evaluation of purpose and actual meaning of findings, a foundation in scientific curiosity rather than a greedy ego.

- **FUNDING:** Most academics and researchers are funded through public money through salaries provided by government, grants by public funding agencies or scholarships by a variety of providers. This funding usually stems from taxes and it is a valid question as to what happens with the taxes we pay. In consequence, publishing the data generated naturally becomes a matter of accountability and integrity, combined with transparency about what the actual contribution to society was achieved. Further, it is a good exercise to work out how much a PhD or any other research project actually costs. Why would anyone be willing to invest this sort of money into training a PhD? It would be healthy to reflect on how a return on this investment can be given to society and the greater good. Being humble and grateful rather than feeling overly privileged tends to lead to much more satisfaction and happiness.
- **IMPACT:** PhD theses are typically published, what used to be microfiche has become books, then pdf files, more and more readily available. Fact is that very few PhDs are read by anyone beyond supervisors, examiners and maybe a handful of very diligent fellow PhD students who wish to learn from previous PhDs in the field. The value of the PhD thesis is predominantly attaining an academic qualification of being able to complete a large project and compile this in a comprehensible manner. The shortcut of the cumulative PhD indicates the obvious – the publications matter a lot more. Anyone able to generate a series of good publications (at IAMT the requirement is 4 that then form the core chapters of the PhD thesis) will succeed with a PhD because this researcher has attained the learning skills of becoming an independent researcher able to conceptualize, carry out and communicate research. The publications are read by the scientific community all over the world. Following the citations can be quite a humbling experience. Being known as an expert, an international leader and becoming 'famous' is a journey that begins at the end of a PhD through these papers that people read. If these are well written with exciting and novel science, the news spreads quickly, job offers, collaboration propositions and invitations to speak will follow. Obtaining a PhD or promotion is merely (an important) consequence of such good and challenging work and of course a rite of passage.

What makes publications in the field of water process engineering so hard? Other than most engineering researchers not being natural writing talents, the tasks involved in engineering research are inherently complex and this means a lot of stars need to be aligned for things to work as we want. This requires a lot of skills; i) actual experiment needs to be designed, built and parameters chosen such that clear results can be obtained in typically pretty long experiments that produce a lot of water samples *(this is usually our 'expertise' – good membrane experiments with meaningful mass transfer, application relevance and suitable parameter choice – ideally in tandem with model development and material characterization…)*, ii) detection limits and interferences of analytical methods need to match realistic environmental conditions and complex water matrices *(this is typically not our expertise, but a necessity as our sample numbers exceed the use of expensive commercial labs or the capacities of most collaborators and realistic concentrations are extremely low, especially after treatment)*, and iii) validation of data and meaningful error analysis needs to be done *(which needs a lot of critical thinking)*. On average our publications involve 50+ experiments that are a few hours to a day long, with 10 samples for each experiment to be analysed with multiple tools (500+ samples). Easy when things work and excruciatingly frustrating when they don't and technical problems need to be solved, trialing the best of PhDs.

Compared to these experimental efforts, writing is actually very easy, but one needs time without distractions, be that from other team members, family or social media, to concentrate on reading and writing for long periods of time and ultimately know what one wants to say. Then it is just a matter of letting it flow.