05 Unveiling Green Chemistry : The Molecule Way

Interview with Thomas McKeag

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Abstract: This interview with Thomas MCKeag explores his work in green chemistry: focused on minimising toxic substances drawing inspirations in nature's efficient processes. His journey into this field stemmed from a recognition of designing and curating processes at molecular-level, thus minimizing hazard and maximising sustainability. He discusses the importance of a systems-based approach, acknowledging the wide-ranging effects of chemical changes within production systems. The interview also covers the hurdles in translating these innovations into real-world applications, including the difficulties of working across diverse industries. Additionally, it touches upon the educational aspects of green chemistry, highlighting the need for interdisciplinary collaboration. He shares advice for those entering the field, stressing the value of specialised knowledge and passion. Overall, the interview offers insights into the principles, challenges, and educational dimensions of green chemistry from the perspective of a bio-inspired design practitioner.

Kalpa, our annual magazine, is exploring biomimicry and nature's influences on design. Nature as a mentor teaches a very self organised effort to 'doing things' with least damage. Design thinking explores these tenets through formative and programmatic interplays that enhance the built environment with values such as adaptability, dynamism, resilience to name a few. We are humbled to have this opportunity of talking to you to gain insights on 'nature' as an inspiration in 'greening' the earth. We thank you for contributing to us by answering the questions stated below:

Q1: We would like to firstly understand what green chemistry is. Could you throw light on how your approach to this strategy started and what were your inspirations?

Green chemistry is a new paradigm for performing chemistry using less toxic materials and methods. The field was founded by John Warner and Paul Anastas in their seminal book "Green Chemistry: Theory and Practice" (. Anastas, P.T. and Warner, J.C. Oxford University Press (2000). Many of the practices of green chemistry are inspired by the processes found in nature.

I came to green chemistry through my bio-inspired design educational practice, and my growing realization of how important design can be at the molecular linear scale. Happenstance, as you will see below, also played a role, but I was quickly inspired by the scientists and engineers at the University of California, Berkeley who were actually designing things, just not at the scale and using the tools that I was familiar with.

Q2: Can you walk us through your first project and its impact/outcome. How has the process evolved to this day?

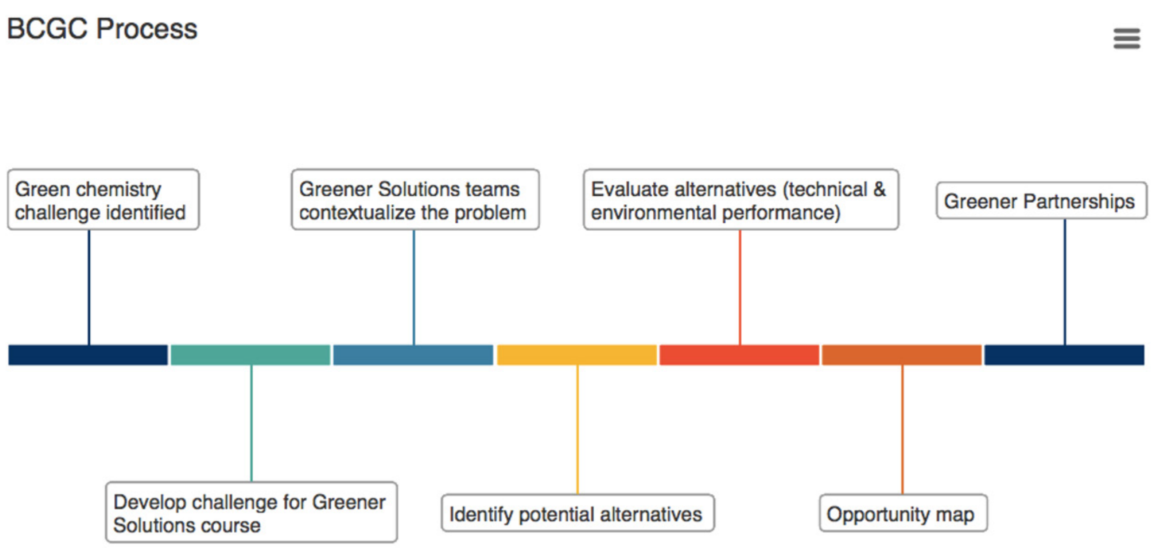
I was asked to join an interdisciplinary team to review the formula for a 3D printer resin for Autodesk in San Francisco, California, USA. The company wanted to make its demonstration Ember printer open source and also was keen to know how safe its resin was. It was in this project that I first collaborated with the UC Berkeley Center for Green Chemistry, eventually joining the group as development director, then becoming executive director.

We analyzed the components of the formula across a comparative chemical hazard assessment and then recommended several general bio-inspired design strategies.

These strategies can be viewed in a subsequent publication by Yale University Press/ Wiley (McKeag, T. A. (2018). Shaping the future of additive manufacturing: twelve themes from bio-inspired design and green chemistry. In Anastas, P. T., Tools for Green Chemistry (241-262). Weinheim, Germany. Wiley-VCH Verlag GmbH & Co. KGaA. ISBN: 978-3-527-32645-7)

This initial work was the start of several years of study, education and project work on additive manufacturing (AM), funded by grants from the US Environmental Protection Agency (EPA), and including graduate course work, presentations at conferences, and further publications. Graduate students in our Greener Solutions course devised several innovative alternatives to standard photo-activated resins, our center developed a green chemistry scorecard for judging AM materials, and we greatly increased awareness of material toxicity issues within the AM community through our outreach.

Below is the process that we employed in our Greener Solutions graduate course. Team members were instructed in bio-inspired processes during the alternative investigation phase (shown in yellow). The course product was always an "opportunity map" which recommended strategies for healthier alternatives within a framework of feasibility.



Source : Author

Our process was always evolving as our collaboration network grew and we learned more about the various industries with whom we were collaborating. In general, we became more aware of the technical implications of linear scale and more attuned to a systems approach. There really is no such thing as a drop-in replacement for a single toxic chemical, and all factors within the production process must be taken into account in presenting alternatives.

Q3: Nature is known for its efficiency and sustainability—how have these qualities been incorporated in the material sciences to balance both functionality and the aesthetics of design?

Much of my individual work has been in additive manufacturing and I think it is a great example of a relatively new technology that incorporates basic principles of efficiency and sustainability in nature: just-in-time manufacturing, functionally graded materials, composite construction to balance stresses, recycling of basic materials, to name a few.

Q4: What are some of the biggest challenges you face when trying to translate these innovations in practice?

There is always an intense ramp-up in acquiring a working knowledge of a field or industry to a level where one can ask intelligent questions. Frankly, this is a pursuit that I enjoy, but there are limits to one individual's capacity to absorb technical information and then synthesize it into coherent investigation strategies, let alone solutions. This is the reason all of our Greener Solutions projects were done by interdisciplinary teams, carefully chosen for a balance in engineering, chemistry and public health expertise.

Staying in the problem space sufficiently to consider a range of factors, being keenly aware of the physical implications of linear scale, and studying, in a systems thinking way, interactions, as well as components, that will yield an outcome. These are all admonitions that the practitioner should heed, in my opinion.

Q5: How has innovation and technology aided your approach, especially when materiality brings in its complexities?

There have been great advancements in the ability to observe the nano-scale world in real-time and this has led to new insights about both materials, and, excitingly, processes that occur in nature. I write about one example of this in an article in issue 24 of our online journal Zygote Quarterly, and one of the young engineering professors at UC Berkeley, Dr. Grace Gu, one of many whom I found inspiring.

Q6: Your innovative strategies are spread across varied markets and scales, be it clothing, industrial use, beauty, household products etc. What or who has been the easiest recipient of this technology (both market-wise and end user response) and on the other hand, who has been the most challenging?

BCGC does indeed have a record of diverse partners from various industries. These partners, almost entirely, have come to us for help with an issue, so our projects begin with a motivated partner. In my experience within the market, however, personal health and safety, whether in food or personal care, is an area where adoption is usually easiest, with the market pull from concerned consumers motivating companies who want to do the right thing or to gain an advantage or keep their customers.

Ironically, while the additive manufacturing industry may seem the most similar to nature from a technical standpoint (the antithesis of "heat, beat and treat" of traditional manufacturing), it has been challenging to inculcate its green chemistry adoption. Proprietary formulas, intense competition and fast changing and disruptive technologies make the industry participants hesitant to share information. This is why the Autodesk project cited above was such a ground-breaking opportunity for us.

Q7: In terms of outreach, what has been your experience in advocacy - be it in education, policy or even law?

Most of my experience has been in education, although at different levels, both formal and informal. I have had limited experience in affecting policy or law. Within education, I think the green chemistry community has made great strides, particularly with progressive companies, although green chemistry approaches are still a tiny fraction of activity in the chemical industry itself. Toxicology and public health are still not standard requirements in the education of chemists, but that is slowly changing. The United States, unfortunately, regulates chemicals through a bewildering patchwork of different agencies and powerful lobbies have consistently thwarted more comprehensive regulation.

Teaching innovation does require the synthesis of different fields of knowledge, so I found in drafting a so-called "export model" of our Greener Solutions process that, *as in nature, you should not produce a blueprint, but rather a recipe; one that can be adjusted for local conditions, capabilities and audience, and accept that the result may not be the same, but might work for the recipient.*

Q8: Lastly, what would be your words of wisdom, firstly, with students in exploring this specialisation as a practice and secondly, to young practitioners who are pursuing to set a mark?

For bio-inspired design practitioners I would refer you to our latest issue 36 of Zygote Quarterly and my article on D'Arcy Thompson: "On Growth and Form: Six Lessons for Designers". Although a broad knowledge of many fields is necessary, do make sure you have one deep expertise that you can bring to an interdisciplinary team of equals. This is the so-called "T" model advocated by many (broad at the top, but deep in at least one subject). Focus on your passion: what gets you out of bed every morning. Without that, work will be drudgery and you probably will only be successful in spite of yourself.

Q9. What would be your advice to academicians across the globe with regards to consideration of context and geographical analysis and its impact on

If I understand the question correctly, I would make sure that you make a typology of all the factors that you might want to investigate or present. For example, whether the subject matter could be considered universally accepted or applicable, or specific to certain conditions. Framing, as mentioned in the above ZQ article, is important, and an attempt to be as comprehensive as possible in investigating parameters is, too. This was the impetus to my developing the Bio-Design Cube (Zygote Quarterly issue 6), as an aid to initial conceptual design.

Thomas McKeag

Tom is the former executive director of the UC Berkeley Center for Green Chemistry (http://bcgc.berkeley.edu), dedicated to advancing green chemistry through research, education and outreach. BCGC hosts the graduate course Greener Solutions, a collaboration with public and private organizations to find safer functional alternatives to common chemicals used in products and processes. Bio-inspired design instruction is an integral part of this course.

Tom is a founding editor of Zygote Quarterly magazine (http://zqjournal.org), taught the BioWerks studio course in Industrial Design at the California College of the Arts, SF, 2006-2015, and was the Biomimicry Column writer at Greenbiz.com, 2009-2015. In 2013-2014, he was a resident Fulbright Nehru senior scholar at the Indian Institute of Science in Bangalore, India. He is the author of Green Chemistry in Practice:Greener Material and Chemical Innovation Through Collaboration (Elsevier) https://shop.elsevier.com/books/green-chemistry-in-practice/mckeag/978-0-12-819674-8