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Training wicked scientists for a world of wicked problems

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Humanity faces a number of wicked problems, from global climate change and the coronavirus pandemic to systemic racism and widening economic inequality. Since such complex and dynamic problems are plagued by disagreement among stakeholders over their nature and cause, they are notoriously difficult to solve. This commentary argues that if humanity truly aspires to address the grand challenges of today and tomorrow, then graduate education must be redesigned. It is no longer sufficient to train students only to be experts in their respective fields. They also must hone the interpersonal and professional skills that allow them to collaborate successfully within diverse teams of researchers and other stakeholders. Here the conceptual framework of *wicked science* is proposed, including what a graduate program in wicked science would achieve and why such training matters both to researchers and the communities where they work. If humanity hopes to effectively tackle the world's wicked problems, then it is time to train a generation of wicked scientists.

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Introduction

As the director of the US National Institute of Allergy and Infectious Diseases, Dr. Anthony Fauci has served seven presidential administrations and battled a long procession of pandemics: HIV, SARS, 2009 H1N1, Zika, and now the novel coronavirus. His job requires that he leverages his scientific expertise in a shifting political landscape, where there is frequently little agreement about the problems at hand or how to best address them. His job, in sum, is to tackle *wicked problems* and in our minds, he is an exemplary *wicked scientist*. By this, we mean he is someone who possesses deep disciplinary expertise yet can also navigate interpersonal and political complexities to tackle the grand challenges of today and tomorrow. We need more wicked scientists like Dr. Fauci.

To train wicked scientists—those who are well-prepared to tackle the world's wicked problems—we need to rethink graduate education. It is no longer sufficient for graduate students to be experts in their respective fields. They need to hone interpersonal and professional skills that allow them to collaborate successfully with diverse teams of researchers and other stakeholders (e.g., community members, policy-makers, activists, businesspeople, government officials—or anyone with a stake in the problem). The growing demand for graduates with both deep disciplinary training and transdisciplinary skills has been identified in numerous reports from organizations like the National Science Foundation, National Academies of Sciences, the Council of Graduate Schools, the Higher Education Academy, and UNESCO (Sterling, 2012; Denecke et al., 2017; Leshner and Scherer, 2018). The cultivation of interpersonal and professional skills, or cultural competencies (Hora et al., 2018) is especially critical for realizing what is known as the diversity bonus—the benefit teams gain from generating new ideas through the diversity of their members (Page, 2017).

While interdisciplinary and transdisciplinary programs are increasingly common in higher education (Wiek et al., 2011; Pennington et al., 2019), they are usually designed to bring together researchers of distinct disciplinary backgrounds (i.e interdisciplinarity) or researchers and other stakeholders (i.e. transdisciplinarity) to investigate clearly defined problems of common interest and understanding. Wicked science, by contrast, tackles grand challenges that affect diverse groups of stakeholders who disagree about the nature of the problem and its causes. Since these problems are highly complex and marked by divisiveness, they are notoriously difficult to solve. Wicked problems thus require disciplinary expertise and transdisciplinary skills but also purpose-driven commitment to problems that defy easy resolution and require stakeholders to work across ideological and epistemological differences. This means that wicked problems are not just scientific problems but also political problems. If we want to effectively address these grand challenges, then our approaches to scientific practice and graduate training must account for these wicked realities.

Wicked problems are complex *and* political

The standard scientific approach is to conceptualize problems as having straightforward technical solutions. However, ignoring the complexity and socio-political dimensions of such problems can have serious consequences. The COVID-19 pandemic is exemplary in this regard. How different social groups perceive and respond to mask mandates, social distancing guidelines, and vaccination, among other factors, has significantly shaped this public health crisis and its impacts.

The scholars Rittel and Webber (1973) were the first to introduce the concept of wicked problems, outlining their basic characteristics and accompanying challenges. First, they noted that wicked problems are complex and without clear boundaries. In the case of the COVID-19 pandemic, it touches all aspects of society, i.e., it is unclear where the problem ends and the context begins. Second, there are no perfect or permanent solutions, and solutions inevitably change the system in ways that are difficult to assess. For example, vaccines lead to better health outcomes overall, but not everyone will opt to vaccinate or follow public health guidelines, and the virus will continue to mutate. Third, the range of solutions is limited by what is feasible and what is imaginable. The failure to prepare for the global pandemic is reflective of both the inconceivability of the problem as well as a lack of political will to heed the warning of those who identified this looming threat. Fourth, worldviews shape how all stakeholders, including researchers, envision the problem and its solution. This is always the case, but in the current geopolitical climate this poses an almost intractable problem as different understandings of the severity of COVID-19 follow political lines in many countries, including Brazil, India, and the USA, among many others.

The concept of wicked problems not only effectively captures the complexities inherent to the coronavirus pandemic but also a wide range of other grand challenges, including climate change, food and water insecurity, growing socio-economic inequality, cyber security, and systemic racism. Rittel and Webber (1973) note that because wicked problems are complex and political, it is impossible to "solve" them. However, we argue that training researchers to work effectively in inclusive, transdisciplinary teams that consider both the complexities *and* politics of wicked problems, will lead to more sustainable and equitable outcomes, even if the problems are never permanently solved. Our reasoning is that transdisciplinary teams are better equipped to "center the margins," or bring both issues and individuals that are marginalized to the fore (see, e.g., hooks, 2000).

Although much has been written about the challenges of wicked problems (DeFries and Nagendra, 2017) and the need to address them (Brown et al., 2010; Wade et al., 2020), this has not yet prompted the development of programs that train graduate students to tackle grand challenges in transdisciplinary research teams (National Research Council, 2014). For this reason, we see the development of training programs in wicked science as being long overdue.

Training wicked scientists

"Wicked science" is not merely a catchy term or an attempt to introduce a new scientific buzzword. We use this neologism because it accurately and effectively describes our conceptual framework for training graduate students to tackle the grand challenges of our time, as well as those of the future. Specifically, this entails training graduate students to be able to:

1. Tackle wicked problems using a systems-thinking approach that considers the political roles, interests, and perspectives of stakeholders.
2. Collaborate effectively with stakeholders and team members with diverse backgrounds, life experiences, and ways of knowing.
3. Communicate scientific research and ideas to diverse audiences and through different modalities.
4. Meet ethical, collegial, and professional expectations and standards in collaborative research and other professional endeavors.
5. Articulate a sense of purpose and develop competencies, skills, and habits that prepare them for life-long learning about and engaging with wicked problems.

While the development of these competencies surely overlaps somewhat with those identified in other transdisciplinary programs (Wiek et al., 2011), what sets the learning outcomes for this program apart is that they are tailored to the dual scientific and political nature of the concept of wicked problems and thus prepare students to develop and refine skills that can lead to sustained and effective engagement with such grand challenges. This includes, for example, recognizing the different epistemological and ontological assumptions that stakeholders have about the problems at hand, and learning how to work across such differences in practical and equitable ways. Wicked science also encourages early career scientists to commit to problems that defy simple resolution but are nonetheless characterized by urgent mutual concern (i.e., shared concerns of researchers and other stakeholders). This means that wicked problems—and the strategies devised to address them—cannot be defined by scientific experts alone.

To be sure, training wicked scientists requires an innovative approach that involves hands-on training in skills that make transdisciplinary teams inclusive and successful. A *hacking wicked problems* practicum, for example, would include small interdisciplinary teams of students working with stakeholders to tackle specific wicked problems in local communities, e.g., homelessness, food insecurity, drug epidemics (McMurtrie, 2019). At our home institution (the Ohio State University) different research groups are tackling the wicked problem of food insecurity in the City of Columbus (Kaiser et al., 2015; Sweeney et al., 2015), which could serve as cases in the hacking wicked problem practicum. And since becoming a wicked scientist is not a solo or short-term proposition, participation in a *community of practice* in which students continue to engage after graduation is essential (Lave and Wenger, 1991). Such a community would engage students, alumni, faculty, and other stakeholders, and foster long-term professional learning through events, seminars, and workshops.

We can already see wicked science being enacted by innovative research groups, such as the Civic Laboratory for Environmental Activist Research (CLEAR) at Memorial University in Newfoundland, Canada. Led by Dr. Max Liboiron, CLEAR studies marine plastic pollution—a wicked problem that impacts diverse communities and may never be fully "solved." Since its inception, CLEAR—which is grounded in a feminist and anti-colonial scientific praxis—has developed novel methods that emphasize humility, equity, and good land relations, including Indigenous data sovereignty contracts, guidelines for equity in author order on research publications, protocols for community peer-review, and open science tools for plastic pollution monitoring, among many others (CLEAR, 2018; Liboiron et al., 2018a; Liboiron et al., 2018b). Rather than avoid the political dimensions of scientific research or claim to be "apolitical," CLEAR has developed a scientific approach that aims to build more just and equitable transdisciplinary research methods and partnerships. In doing so, it asks its researchers and community partners alike to cultivate a different vision of what science can look like and what it can ultimately be. The challenge now is to expand on the efforts of labs like CLEAR to train a generation of wicked scientists.

Changing graduate education: challenges and opportunities

We acknowledge that developing graduate training programs in wicked science will meet various challenges in the process of implementation. One could argue that developing such a transdisciplinary program is in itself a wicked problem. While many would agree that we need better training programs to tackle the world's wicked problems, fewer might be willing to commit to the structural changes needed in higher education to achieve this goal.

One common concern is how to strike a balance between disciplinary training in home departments and transdisciplinary training in wicked science. We are sensitive to the fact that graduate students already have many demands on their time and we are wary of adding more to their plates. One way to address this concern is through institutional mechanisms that encourage transdisciplinary training and coursework. For example, the Ohio State University offers Graduate Interdisciplinary Specializations—what are essentially graduate minors—that allow students to develop expertise in fields outside of their home department that count toward their overall credit hours needed to complete their graduate degree.

To be successful, it is also important for individual departments and faculty members to recognize the value of transdisciplinary work and encourage this path for their students. This, then, calls for cultural change within departments to acknowledge and "count" research that has important impacts beyond the academy but which may not always result in specialized journal publications or other conventional scholarly outputs.

Beyond the tensions between disciplinary specialization and transdisciplinary training, there is also significant pressure on graduate students to prioritize individual achievement. Many feel pressure to distinguish themselves in a hypercompetitive job market by publishing early and often. Recent research in sociology shows that starting Assistant Professors today have published on average twice as much as their predecessors in the same position 20 years ago (Warren, 2019). Not only is this trend unsustainable and encouraging of bad science (Smaldino and McElreath, 2016), but it also creates disincentives for early scholars who otherwise would want to develop transdisciplinary research geared towards tackling pressing social problems. Instead, junior scholars are incentivized to study a small piece of a bigger puzzle and then divide that piece into many smaller units for publication. Famously, Peter Higgs, who gave his name to the Higgs boson particle, remarked that no university would hire him today because he would not be considered "productive" enough (Aitkenhead, 2013). He nearly lost his job in 1980 but was saved by a Nobel Prize nomination that same year. Clearly, the cult of productivity that fixates on short-term, maximized, quantifiable output requires serious re-evaluation and change.

In light of the current academic job market and outsized expectations for new tenure-track faculty, many graduate trainees are understandably seeking careers outside academia. Training as wicked scientists can help graduate trainees on this path. Faculty can specifically help by: (1) teaching interdisciplinary skills alongside specialized disciplinary training; (2) communicating research in modalities other than peer-reviewed articles; (3) developing research collaborations that go beyond the walls of the academy; and (4) committing to tackling socially relevant research problems. This model of wicked science will not only serve the next generation of graduate trainees, but it will also serve the university as a whole, including students, faculty, and administrators who are seeking cultural and institutional change in higher education.

Conclusion

Despite the widespread adoption of wicked problems as a concept in the sciences, we have argued here that it has yet to translate into training programs designed specifically to tackle these grand challenges. This article is only a mere starting point to outline some of the organizing principles for training wicked scientists. Though there is considerable overlap with existing approaches—in particular, sustainability education—there are important differences and distinctive features of our proposed model. First, since wicked science does not fixate on any one problem, it prepares trainees to potentially tackle a wide range of wicked problems, including the societal ramifications of artificial intelligence, drug epidemics, and systematic racism, among many others. Because wicked problems are everywhere, they transcend disciplines and fields of study. Second, while there are existing programs that train transdisciplinary researchers, these programs are still the exception as there is considerable resistance to interdisciplinary programs particularly at the department level where decisions are made about faculty hiring, tenure, and promotion as well as graduate student evaluation and funding. In other words, if we want wicked graduate training to succeed, we need to push for more wide-ranging changes in academia. Third, the training of transdisciplinary scientists generally focuses on the technical complexity of wicked problems, but often sidesteps or gives lip-service to the politics of wicked problems, including underlying epistemological and ontological assumptions of stakeholders, which is a critical component of the training of wicked scientists. Finally, since wicked problems are intractable, students need not only develop interpersonal skills to work effectively in transdisciplinary teams, but also cultivate a sense of purpose that allows them to engage problems that defy simple resolution but nonetheless are matters of urgent mutual concern.

Some researchers might prefer to avoid getting embroiled in political debates or thorny social problems. Some might even suggest that “wicked science” is nothing more than politics by another name. However, we argue that we cannot stay on the sidelines, especially if we recognize that we are facing societal collapse, planetary destruction, and incredible losses of life, of all kinds. As Dr. Fauci has shown us, we really have no other choice as scientists: we are forced to engage with the complexities and politics of wicked problems. If we want to effectively tackle the world’s wicked problems, we need to train wicked scientists.

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The authors declare no competing interests.

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