The Power and Promise of Citizen Science

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A recent essay[1] by Philip Mirowski has caught the attention of the Citizen Science community, by raising some trenchant questions despite several questionable assertions and assumptions about the Citizen Science movement.

The main thrust of his essay is that Citizen Science is being coopted by "Big Business", however one choses to define it, and that those who promote Citizen Science are, at best, being played if not actively in league with these corporate actors. He further asserts that the Citizen Science movement seeks not to supplement, but to supplant conventional science, employing imagery of storming citadels, overthrowing ivory towers, and similarly vivid metaphors. Mirowski's critiques of the overall venture rests on flawed understandings of the nomenclature and the nature of the scientific enterprise generally. This is perhaps understandable, since the discussion over the term "citizen science" has taken a lot of energy and is ongoing.[2] Mirowski does render some service in the end, however, because he provides a springboard for clarifying just what citizen science is about and, exploring where it might lead.

What is Citizen Science?

One of his first claims is that the term citizen science "carries the unsubtle suggestion that science should be a participatory *democracy*, not an unpalatable, autocratic regime." (Italics in original) I have been involved in citizen science since the late 90's, when it was still called "amateur science" and I have never heard anyone make so extraordinary a claim. In fact, there is a general understanding that science is not, and never has been, open to just anyone who wishes to advance any old theory or data set. When I was working for the Society for Amateur Scientists, we occasionally received treatises claiming to have solved some major conundrum in quantum physics, or declaring that Einstein was dunce, and so on. We undemocratically consigned these works to well-deserved oblivion.

I think that a comparison with the current controversy over free speech on university campuses is instructive in this context. It is easy to confuse the right of free speech with the values of academic discourse; they are not the same thing. Stanley Fish, someone with whom I frequently disagree, nevertheless summarizes the distinction in a way that, I think, also represents the functional reality of science, professional or otherwise. "Freedom of speech is not an academic value," says Fish.

> "Accuracy of speech is an academic value; completeness of speech is an academic value; relevance of speech is an academic value. Each of these is directly related to the goal of academic inquiry: getting a matter of fact right."[3]

Citizen science may be guilty of missteps, but confusing the right to speak with the privilege of being taken seriously is not one of them.

The confusion behind Mirowski 's misunderstanding turns on the word "citizen" which he links to citizenship in "science," which he associates with some monolithic bloc of "elites" who, he further points out, are suffering under a crisis owing to "the traction and replication crises that have besieged

academic journals suggest[ing] that 'proper' science might not be so proper anyway." Leaving aside his apparent surprise that doing science is difficult, I would be far more concerned by a consistent, near-unanimous chorus of confirmations. *That* would be reason worry.

Science and Citizens

But I digress. Even if "citizen science" or "citizen scientist" is a neologism, the activity itself is not; the "citizenship" in question is not scientific, but civic. There is a long and sometimes colorful relationship between the U.S. government and her citizens with an interest in science.

It was a very hot day on July 4th, 1776 when Thomas Jefferson affixed his signature to the Declaration of Independence. We know this because Jefferson also recorded the local air temperature four times. An even better example is when Benjamin Franklin in his role as postmaster asked his far-flung postal clerks to take regular weather measurements and forward them to him. Using this data, Franklin created the first modern weather charts, which revolutionized our understanding of weather. The successors of Franklin's postal clerks continue today in the form of thousands of volunteer weather observers, whose careful and regular observations form a critical data source for the daily weather forecasts and studies of climate.

Non-governmental groups also produce important information by using amateurs. The American Association of Variable Star Observers has, since 1911, collected accurate and plentiful measurements of variable stars by their corps of well-trained amateur astronomers. Even professionals who study variable stars turn to AAVSO on a regular basis to tap their observational data. We could also include the Audubon Christmas Bird Count, which has provided information on avian wildlife since these annual censuses began in 1900. The most recent one I was able to find (2012-2013) involved over 54,000 observers in 17 countries. The amateur radio fraternity has, for decades, conducted research on radio wave propagation and, more recently, explored innovative and robust formats for transmitting digital information. They have also, for many years, served as an entry point for laypersons interested in learning about electronics and electronic circuit design and construction.

Returning to government-run efforts, one of my personal favorites is "Operation Moonwatch." a government program that used volunteers trained in the tricky and exacting art of tracking satellites ("artificial moons") using telescopes. Moonwatch was created in anticipation of the launch of a Soviet earth-orbiting satellite, mainly as a supplement to radio tracking. When Sputnik launched sooner than expected, these men and women were the only available means for tracking the satellite; the primary tracking systems were still incomplete. Once Sputnik's battery died and the signal failed, optical tracking continued, both for Sputnik and for other satellite launches.[4]

Government encouragement of citizens doing science went beyond "mere" data collection. Among the occupants of my overburdened bookshelves is a little 53-page pamphlet published by the U.S. Army School of Artillery and Missiles. It is a how-to book for amateur rocket enthusiasts. Published in 1959, this document gives a brief but remarkably complete overview of how to design, build, and launch rockets. Aerodynamics, engine design, fuel formulation, ignition and launch systems, testing and performance analysis… it's all there. The Preface recognizes the surge of interest among high school and college students in rocketry, and notes:

> "We foresee great benefit to our nation as a consequence of this scientific curiosity on the part of the generation which will soon bear the responsibility for our scientific progress. The United States Army desired to extend the maximum degree of cooperation to those budding scientists in their experimentations."[5]

These are only a few of many examples one could cite. The truth of the matter is that the United States included among her founders some of the leading scientific minds of the day. They crafted the nascent government in order to give advantage to men like themselves; inheritors of the Enlightenment who placed a high premium on intellectual freedom.

"An alert and knowledgeable citizenry"

But if one really wants to get back to the connection between "citizen" and "science," there can be no better starting point than the famous Farewell Address[6] given by President Dwight Eisenhower at the end of his presidency. This speech is justly famous for giving us the phrase "military industrial complex" which had been built under his administration to hold the threat of Soviet communism in check. Eisenhower clearly understood that the military and political necessities behind this massive military undertaking constituted a deal, if not with the Devil, then with darker aspects of our national character. He warned against how the increasing flow of government research funds into the university meant that, "a government contract becomes virtually a substitute for intellectual curiosity... The prospect of domination of the nation's scholars by Federal employment, project allocations, and the power of money is ever present -- and is gravely to be regarded." Eisenhower continued:

> Yet, in holding scientific research and discovery in respect, as we should, we must also be alert to the equal and opposite danger that public policy could itself become the captive of a scientific-technological elite.

And who would hold the line against these encroachments into public policy and the general welfare?

> "Only an alert and knowledgeable citizenry can compel the proper meshing of the huge industrial and military machinery of defense with our peaceful methods and goals, so that security and liberty may prosper together."

I submit that Eisenhower's statement is a mandate for scientific involvement by citizens, as citizens, both for the reasons given by Eisenhower, and to expand and augment how science is done.[7]

This does not, *contra* Mirowski , mean a takeover of government or corporate science by unruly mobs of citizen scientists. In one of his more remarkable sections, Mirowski claims that "The EPA has shed a large part of its workforce of credentialed scientists and replaced them with 'citizen' data-gatherers." He makes reference to an unspecified "recent National Environmental Monitoring Conference"—no citation is given—where "the issue was raised as to whether citizen scientists were being used to offset recent budget and personnel cuts." He does not mention how the issue was raised, nor how the conference settled the matter, though the EPA's position on such things is quite clear. While it is true that the EPA has struggled in a hostile political atmosphere, and there is arguably a war on expertise,[8] (we can provisionally agree with Mirowski on that point) the EPA's own publications are firmly against replacing credentialed, scientific experts with citizen scientists. Instead, they very sensibly call for partnerships. Per "Environmental Protection Belongs to the Public: A Vision for Citizen Science at EPA," published in 2016,

> "Citizen science should complement—rather than replace—current regulatory and enforcement processes. EPA, however, should work in partnership with individuals and community groups toward more transparent, efficient and comprehensive regulatory processes, including regulatory decisions, regulatory standard setting and enforcement."[9]

This points out an additional difficulty with Mirowski 's assertion; the EPA is about regulation and enforcement. The science they conduct is directed to that end. This makes using citizen scientists instead of experts even more problematic.

Eisenhower's plea for an alert and knowledgeable citizenry becomes ironic given the passage of the National Defense Education Act, signed into law on September 2, 1958. This remarkable piece of legislation allocated massive funding increases for education, particularly in science and engineering, in order to meet the threat of emergent Soviet technology. Suddenly, it was both public policy, *and* a matter of national security that the U.S. turn as many of her citizens into scientists as quickly as possible. These scientists were to join the very scientific-technological elite Eisenhower warned against three years later.

The Question of Qualifications

Mirowski is very, very big on qualifications:

> "Being and becoming a scientist doesn't revolve around a hieratic conformity to some transcendent 'scientific method'. Rather, it's the consequence of a long period of immersion in the specific culture of a discipline, such that one begins to be able to perceive what are the valid questions, preferred methods, legitimate styles of research, and so on."

We agree. However, Mirowski 's praise of training is not part of a call to action, but an accusation of what citizen scientists are neither doing nor inclined to do. Expertise is good. No one really disputes that, certainly not in the Citizen Science world. Mirowski claims that supplanting of expertise is "how citizen science is sold", but gives no actual examples of citizen science antipathy towards or contempt for expertise.

But expertise comes in many forms. Undeniably there have been talented amateurs who have done excellent work, but who could not publish in the standard journals because they did not have a degree. Lacking a doctorate or university affiliation, as a young engineer Buckminster Fuller had to "publish" his work by filing government patents. Returning to the matter of qualifications, earlier I mentioned the thousands of volunteer weather observers upon whom we rely for the data behind the national weather forecasts. I'm willing to bet that the vast majority of those volunteers do not have undergraduate or graduate degrees in meteorology or atmospheric science. I am not aware that their qualifications are a source of controversy.[10]

There is also the question of what kind of expertise might be needed. Allow me to cite a personal example. My spouse, Denise Greaves, holds a Ph.D. in Classics from Stanford University. Classics—the study of ancient Greek and Roman languages, history, culture, etc.—which is about as far from quantum computing as is possible to get. However, a deep study of Greek and Latin gives one something akin to superpowers when it comes to evaluating English prose. For this reason, her help was enlisted by our friend Dr. Eleanor Rieffel when she and her co-author Wolfgang Polak asked for her help as an outside editor for their 2011 book, *Quantum Computing, A Gentle Introduction*.[11] In addition to assisting with

the language, Denise was also able to spot instances where the text was unnecessarily vague or difficult. I think this constitutes a contribution, however modest, to the larger scientific discussion.

Denise's editorial assistance was acknowledged in the preface of the book. But it also raises the question of where other seemingly unrelated fields might have bearing on a science project. For example, a study of a local watershed would benefit from input by local historians who could shed light on the industrial and agricultural past of a given area. Local politics and economics long forgotten could explain certain anomalies in the local geographic or legal landscape. Involving a local photographer could be invaluable in documenting a project or, if the photographer happens to specialize in photographing a particular species or phenomenon, he or she might have an existing body of data on which to build. I have seen some indications that citizen science groups are aware of this potential resource and are making an effort to make better use of it. I do hope this becomes a significant trend within the movement. I believe it is a critical element to realizing the full potential of citizen science.

I suggest that if we insist that citizen scientists undergo an academic regimen comparable to their professional counterparts, we risk subjecting the citizen scientist to the same constraints that block research in certain areas, constraints which I will examine shortly. Citizen scientists should be trained, and trained well. However, such training must be designed to help them to capitalize on the unique advantages they enjoy outside the walls of academia and the corporate world. What form this training or credentialing might take remains an open and intriguing question. Training might include a combination of supervised study using informal internships, mentoring arrangements, courses taken at local community colleges or other institutions, online courses (many of which now offer certificates of completion), or otherwise documented life experience. "Qualifications" may take the form of a portfolio, built up over time, including lists of courses taken, articles written, successfully completed CLEP tests, letters of recommendation, completed projects, and so on; not unlike the way artists promote their work and areas of expertise. Sometimes university instructors in odd subject areas can also be hired on the basis of a portfolio. There are many possibilities, but it is important for all concerned to maintain an open mind about how, for example, a Classicist might contribute to a project on quantum computing.

Mirowski would question, perhaps correctly, whether the scientific establishment would go for this given their "elitism." He may have a point. But the question is less, I think, about elitism than it is about the *prestige* associated with science and scientists. While the average plumber makes more than the average scientist (in or out of academia), plumbers are less likely to call attention to their occupation at a cocktail party. Connor Wood's provocative essay, "Science is Classist. That Harms Democracy. Here's a Solution"[12] explores this dynamic as part of the growing distrust of science and scientists among the general public. He points to science's prestige as a sort of social currency that the scientific community needs to spend in order to regain popular goodwill. Wood takes a page from Alexis de Tocqueville, with his observation that for the wealthy elite, "in democratic times one ties the poor to oneself more by manners than by benefits." He further remarks that there must be something in common between elites and the rest of society for cohesion and goodwill to exist. Wood's argument is that science can regain some of its lost reputation by sacrificing some of its prestige; in other words, showing some humility with respect to non-scientists. Fair enough. While Wood makes no mention of citizen science or citizen scientists, I believe that a robust citizen science movement can accomplish just as much if not more to restore public confidence by actively engaging the public in scientific pursuits. Such a movement must truly engage participants and make a strenuous effort to impart practical, scientific know-how, not

merely use them as data-gatherers with no avenues for more interesting activities. This will demand considerable time and effort to accomplish.

Retaining Citizen Scientists

One of the persistent problems facing citizen science is the matter of retention. Unfortunately, a lot of people find the tasks of measurement and data collecting dull and tedious. That's because much of the work involved *is* dull and tedious. An intelligent, curious person isn't likely to find much to recommend the usual tasks assigned to them very fulfilling, even when it's wrapped up in a gamified package. Seeing their name tucked inside a long list of data gatherers when the paper is finally published (assuming the citizen scientists receive any recognition at all), is a faint reward. Surveys of citizen scientists show that the desire to contribute to scientific research is one of, if not the primary motivator.[13] The loss of interest suggests that most citizen scientists soon crave more interesting challenges, and abandon projects when no such challenges are available. Unfortunately, the current practices offer few if any pathways forward for someone who wants to acquire new skills, such as data analysis or experimental design.

This is starting to change. I point, only slightly immodestly, to a Citizen Science 101 course I've written with the support of Ocean Sanctuaries. This course teaches beginners the bare essentials of science; measurement, the metric system, keeping field notes, identifying organisms, sharpening one's powers of observation, and so on. It is very basic, but one needs to start somewhere. Because of the particular interests of Ocean Sanctuaries, the course is weighted heavily to nature study, and marine environments in particular. Those who finish the course will receive a certification that includes a citation, describing exactly what skills were taught in the course. We hope to make the course available to the general public sometime in 2018. Other organizations are working along similar lines.

The problem of retaining citizen science participants shares many characteristics with the retention problems of online schools. As a co-founder and one-time Chief Academic Officer of such a university, we discovered that the retention problem becomes tractable only when there is a significant, sustained program of outreach and involvement. Put another way, distance learning programs need to compensate for the isolation that students feel, unlike their brick-and-mortar counterparts. Citizen scientists will stick around once they feel that they are truly part of a community, and that they play an important role in it.

The Limits of Conventional Science

Citizen science, as it currently stands, does not make the best use of the resources available to it. This is partly due to the fixation on "qualifications" we find in Mirowski and elsewhere. It is also due to constraints that science places on itself, partly through necessary conventions, but also by administrative processes and realities that actually keep scientists from investigating areas with potential for new findings.

Scientists sometimes find that evidence collected during a research project points in an unexpected direction, but they cannot pursue that line of research because the grant does not allow for it. It is also common for a project to falter because the research leads into subject areas outside the expertise of the specialists working on the problem. One also speaks of research that is "theory driven", meaning that the questions asked are based on the theory being tested, which may or may not prove to be a barrier

to more fruitful areas of inquiry. Some areas of research receive more attention than others because a particular faculty member, adept at fund-raising, can support multiple graduate students who then go on to dominate that area at the expense of others that were not so fortunate in the grant hunting game. The following diagram from a colleague of mine illustrates the dynamic:

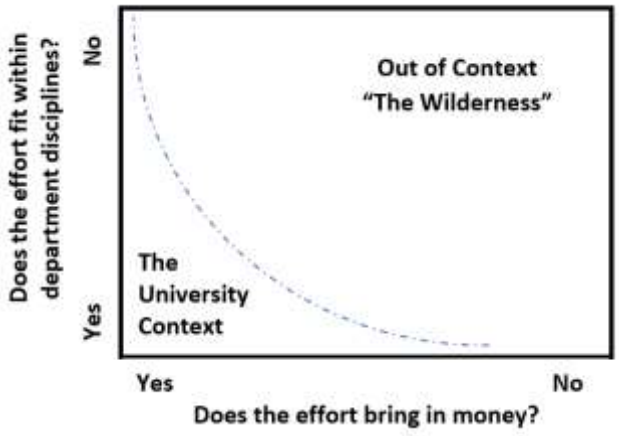

Figure 1: "A Map of Disciplined Inquiry"[14]

The chart illustrates how disciplinary boundaries and available funding create a basin of attraction ("The University Context") that draws research into some areas at the expense of others. Papers and projects that attract funding or show promise for potential patents receive priority (Mirowski's claim that citizen science is being co-opted by corporate America has been true of academia for years.). The rest, even if they pass peer review and see the light of print, languish. It seems clear that The Wilderness represents an area of opportunity for citizen scientists. It is vital to note, however, that The Wilderness is not merely a place for under-qualified hobbyists. There are many scientists, professionals and academics, who have obtained the qualifications, sought and achieved tenure, and published in peer-reviewed journals, whose work has not received the follow-up and examination that perhaps it should have, not because it lacks merit, but because of the dynamics described in Figure 1. Many of these scientists have left academia in frustration or retired and might welcome an opportunity to dust off a previous, unfinished project. Add to that the growing number of newly-minted science graduates who cannot find work in their field of study, or the ABD (All But Dissertation) grad students who had to give up their studies, but still retain a passion for the subject. The problem is that there isn't a community for scientists and graduate students who find themselves in The Wilderness. Citizen Science can become that community.

The effectiveness of the training paths mentioned earlier would be significantly improved by linking untrained citizen scientists with professionals and graduates who can play a mentoring role along with leading and guiding independent projects.

This brings me to one of the areas where, I submit, citizen science has yet to make a serious contribution: the interface between the scientific community and the general public. I touched on this earlier in connection with Wood's essay, but it bears revisiting. In years past, up until the mid-eighties or nineties, there were scholars known generally as "public intellectuals." Some were academics, many were not. These men and women took it upon themselves to interpret the work of their academic colleagues for the general public, and often made original contributions of their own. But they also did

more. They displayed a flair for working across disciplinary boundaries, and did so with an intellectual style that Irving Howe once described as, "free-lance dash, peacock strut, and knockout synthesis."[15] Because their work ranged over so much intellectual territory, they found ways to get disparate parts of the academy talking to each other. These conversations prompted fresh thinking and syntheses.

One problem that confounds many experts in talking to other experts is that they frequently talk past each other, especially where the subject is controversial. Citizen scientists can play a role in facilitating needed dialogue by using a technique described by Daniel C. Dennett in his book, *Intuition Pumps and Other Tools for Thinking*.[16] The technique works as follows: a discussion between two experts or panels of experts is moderated (one might say "refereed") by a panel of intelligent laypersons who are not experts in the subjects under discussion. In making their presentations, the experts direct their remarks to the laypersons, who are empowered to ask experts to back up, explain, and define, as needed. Experts may not answer a question by giving "homework assignments" ("Oh, to understand that, you need to read Heidegger!") as part of their explanations. Dennett recounts that in these exercises, because experts no longer have recourse to unspoken (and sometimes unexamined) assumptions, group think, insider jargon, and other shortcuts, they often come away with a better understanding of their own subject areas, and "opposing" experts better appreciate the nature of the controversy. It is not hard to envision Citizen scientists setting up informal forums for these kinds of discussions. They are not unlike the salons of Europe in the 18th and 19th centuries where much of the intellectual and political ideas of the day were explored and tested.

Is Citizen Science a Revolution?

One of the sharper critiques in Mirowski's essay disputes the notion that citizen science is "a revolution" (however one chooses to define it). He argues that gamified science projects such as Galaxy Zoo constitute little more than a corporate power grab in which well-meaning enthusiasts are merely pressed into service for the sake of corporate profits. Others argue that citizen scientists are merely the newest, lowest rung on the academic ladder right below graduate students; flunkies for academics but without the potential of getting a degree. Citizen science as an activity is not new, as we have seen, so it is not "revolutionary" in that sense. It is definitely taking lay participation in science into some new areas, but serious retention problems suggest that this revolution lacks staying power.

Citizen science also offers too few paths to expertise for its participants. We have offered some suggestions to address this, but to do this well requires a diverse, engaged community of experts and laypersons working together. Many, perhaps most of the piece exist by which new scientific ventures can emerge in areas neglected by conventional investigations. Citizen science can become a revolution, but only once it becomes a true community, prepared and empowered to advance into areas of inquiry alongside its professional counterparts.

About the Author

Sheldon Greaves holds a Ph.D. in ancient Near Eastern Studies from the University of California at Berkeley. He is a co-founder of Henley-Putnam University, a nationally-accredited online university serving the intelligence and counterterrorism communities. He was a board member for the Society for

Amateur Scientists from 2001 to 2003. He also founded Tinker's Guild, which published the complete collection of *Scientific American's* "The Amateur Scientist." In 2010 he founded the Citizen Scientists League, which he directed until 2013. He is currently on the Board of Directors for Ocean Sanctuaries.

Notes:

[1] "Against Citizen Science" Aeon. https://aeon.co/essays/is-grassroots-citizen-science-a-front-for-big-business?utm_source=Aeon%20Newsletter&utm_campaign=1959de3688-EMAIL_CAMPAIGN_2017_11_19&utm_medium=email&utm_term=0_411a82e59d-1959de3688-68641861

[2] Eitzel, et al. "Citizen Science Terminology Matters: Exploring Key Terms" Blog: Citizen Science: Theory and Practice. https://theoryandpractice.citizenscienceassociation.org/articles/10.5334/cstp.96/, accessed 08 December 2017.

[3] As quoted in Bill Moyers, "In the Age of Trump, a Chilling Atmosphere," http://billmoyers.com/story/academic-freedom-age-trump/, accessed 29 November 2017.

[4] For a good treatment of this program, see W. Patrick McCray's *Keep Watching the Skies! The Story of Operation Moonwatch and the Dawn of the Space Age*. Princeton University Press, 2008.

[5] *A Guide to Amateur Rocketry.* U. S. Army Artillery and Missile School, Fort Sill, Oklahoma, 1959.

[6] Dwight D. Eisenhower, Farewell Address, delivered 17 January 1961. American Rhetoric, Top 100 Speeches. http://www.americanrhetoric.com/speeches/dwightdeisenhowerfarewell.html, accessed 29 November 2017.

[7] A useful and thought-provoking retrospective on the Farewell Address is Dave Bella, Ph.D., "Democracy and Technology", *Frontiers in Education '90*, Conference held on 2-8 July 1990, Budapest, Hungary and Vienna, Austria.

[8] The reduction of experts in government really started around 1995 in the aftermath of the mid-term elections. See Paul Glastris and Haley Sweetland Edwards, "The Big Lobotomy" *The Washington Monthly*, June/July/August 2014. http://www.washingtonmonthly.com/magazine/junejulyaugust_2014/features/the_big_lobotomy050642.php?page=all, accessed 29 November 2017.

[9] National Advisory Council for Environmental Policy and Technology (NACEPT), "Environmental Protection Belongs to the Public: A Vision for Citizen Science at EPA", December 2016, EPA 219-R-16-001, p. 49. Obtain the full text at: https://www.epa.gov/sites/production/files/2016-12/documents/nacept_cs_report_final_508_0.pdf.

[10] On the other hand, non-expertise can also manifest in unexpected places: I am aware of at least one professional astronomer who is a world-class theorist and physicist, but who couldn't find the Big Dipper if his life depended on it. Specialization, the academic's boon and bane, puts its own stamp on the problem of qualifications, although it seldom receives the attention it could. However, I have discovered that if one can get most academics talking socially, especially after that second drink, you might hear some confessional and often entertaining stories of the blind spots found among experts.

[11] Rieffel, Eleanor G. and Wolfgang H. Polak. *Quantum Computing: A Gentle Introduction*. The MIT Press, 2011.

[12] http://www.patheos.com/blogs/scienceonreligion/2017/08/science-is-classist/, accessed 07 December 2017.

[13] M. Jordan Raddick, et al. "Galaxy Zoo: Motivations of Citizen Scientists". White Paper, no date, c. 2012.

[14] My thanks to Dr. Dave Bella for his permission to use this graphic.

[15] Cullen Murphy "Religion and the Cultural Elite" *Atlantic Monthly,* 07 April 1994, https://www.theatlantic.com/past/docs/unbound/cullen/cmrel.htm, accessed 07 December 2017.

[16] Dennett, Daniel C. *Intuition Pumps and Other Tools for Thinking.* W. W. Norton, 2013.