the WINNOWER

SCIENCE AND SOCIETY

Training Scientific Generalists: Response to Comments and Additional Thoughts

GOPAL SARMA [1]

1. School of Medicine, Emory University

In several recent articles, I proposed the creation of new graduate programs aimed at training scientific generalists. Here, I collect and respond to a number of comments and criticisms raised in response to these proposals.

READ REVIEWS

WRITE A REVIEW

CORRESPONDENCE:
gopal.sarma@emory.edu

DATE RECEIVED:
July 05, 2016

DOI:
10.15200/winn.146774.41097

ARCHIVED:
July 05, 2016

KEYWORDS:
scientific education, reproducibility, peer review, postdoctoral research, MD/PhD programs

CITATION:
Gopal Sarma, Training Scientific Generalists: Response to Comments and Additional Thoughts, *The Winnower* 3:e146774.41097 , 2016 , DOI: 10.15200/winn.146774.41097

INTRODUCTION

The phrase “age of specialization” is often used in contemporary discussions about 20th-century scientific trends. As an example, a Google search for “age of specialization” returned 296,000 hits. Recently, I made several proposals for graduate programs aimed at training a critical mass of scientific generalists, that is, broadly educated scientists who would play a crucial supportive role amidst a culture of hyper-specialization (Sarma 2016a; Sarma 2016b).

Below, I summarize and respond to a number of comments and criticisms that were raised in response to these proposals. In addition, I express a few more thoughts while reflecting on my initial suggestions.

RESPONSE TO COMMENTS

The suggested program involves extending and adding additional layers of complexity to an already protracted PhD.

The aim of the proposal is to create a new type of PhD program, not to alter the structure of existing ones or to create new hurdles for students pursuing a more traditional track. While I think it is an open question what fraction of trained scientists should be of the “generalists” variety, my intuition is that it would not significantly impact the pipeline of standard graduate training.

Interdisciplinary PhD programs already exist.

Interdisciplinary PhD programs are created when there has been an organic integration of topics from different disciplines that define a new field or set of research problems. In a sense, interdisciplinary programs effectively fail to be interdisciplinary the moment they are created- they simply define a new discipline or a new niche. For instance, while computational neuroscience was at one time an interdisciplinary field, it has grown to the point where it is effectively a subject of its own. Culturally, it is no longer novel to point out that there are deep connections between computer science and biology. The integration between the two disciplines is of such an enormous magnitude that it is widely understood that new research directions will appear periodically. Many of these new directions are best suited for specialized training integrating knowledge from different fields, whether in computational neuroscience, statistical genetics, or medical informatics.

The aim of my proposal to train scientific generalists is quite different. In particular, the value added of

such a program is that with enough students, there would be a large number of individuals who are exposed to different subjects at the graduate level that do not necessarily have the well-defined intellectual coherence of an interdisciplinary program. The objective is for students to undergo an "anthropological exposure" to different subjects so that there is a critical mass of individuals who appreciate the starkly different cultures that make up the highly specialized landscape of modern science. It is not necessary that these subjects define a contemporary set of research problems.

The stated objective is better served by post-doctoral training. These programs, such as ones to train PhDs to enter science policy, already exist.

The post-doctoral programs that currently exist, such as ones in science policy, are designed to train scientists to tackle reasonably well-defined, contemporary issues and navigate governmental or non-governmental organizations that would otherwise be unfamiliar territory for a PhD student.

The difference between this type of training and what I am proposing is analogous to the difference between studying the politics, history, or economic policies of a foreign country versus actually visiting the country, learning the language, and absorbing the culture. There is a need for people to do both. In the scientific realm, we do not have programs that expose individuals to multiple subjects at the graduate level. Generalist PhD programs have the potential to play a significant role in allowing us to address future hurdles that may not be so visible from the realm of current science policy.

That being said, I think it is worth considering if a generalists training program should take place after a normal research PhD. I explored this possibility to some degree in the first manuscript and also discuss related ideas below.

While the proposal has merit, qualifying examinations do not train critical thinking skills.

I suspect that opinions on this topic vary widely from subject to subject. I certainly felt that my qualifying examination in physics was a valuable period of maturation and improved my critical thinking skills. For instance, many physics departments teach courses on "order of magnitude physics," i.e. a set of problem solving strategies to arrive at rough quantitative estimates from basic physical principles without precise calculation. Many consider this type of thinking to be a defining aspect of the training of a physicist, and in addition, one of the most valuable skills that physicists bring to areas outside of physics. In other cases, such as applied statistics, the knowledge gained in preparation for a qualifying examination would be immediately applicable in many domains. The maturity and judgment of how and when to apply these tools will develop over the course of an individual's subsequent career.

Still, I think there are legitimate reasons to question whether a series of qualifying examinations is the best way to achieve the objective of training generalists. I explore this issue in more detail below.

The author suggests training generalists as a means to address the "reproducibility crisis," but these are independent issues.

In the article titled "Is There Value in Training Scientific Generalists for Positions at the Edge of Academia?" I highlighted 3 significant contemporary problems in science:

1. The overproduction of PhDs relative to the availability of faculty positions.

2. A "crisis of reproducibility" in which large subsets of the research literature across multiple disciplines have been called into question.

3. The creation of many positions within academia and on the periphery that require advanced scientific training but where the day to day responsibilities are not aimed at advancing specific research objectives. In other words, positions where the required skill set does not necessarily align with the skills of the best scientific specialists.

The purpose of emphasizing the reproducibility crisis is that it is a serious problem that we are just now

beginning to understand and which, in the broadest of terms, is a direct consequence of the explosive growth of the scientific enterprise following the Second World War. My argument is that continued growth is likely to give rise to other complications that we cannot currently anticipate and that training a sufficient number of generalists has the potential to play a critical stabilizing role over the course of many years. It is not intended to be a short-term solution for addressing issues relating to reproducibility. However, the reproducibility crisis should provide us with strong motivation to think about the long-term future.

The proposal is simply another sign of the worrisome trend towards credentialism and educational inflation.

These trends and their impact on the job market are real and are important discussions in the context of graduate education. However, they have very little relation to the specific obstacles faced by the research world. To the extent that I emphasized ensuring that graduates of a generalist PhD program have immediately employable skills, it is only to provide them with a safety net, given the novelty and uncertainty of participating in a newly created intellectual and career path.

Therefore, while I do perceive the need for generalists as a sign of the increasing size and complexity of modern science, it is unrelated to credentialism and educational inflation in other areas.

For a program like this to serve the students' needs, the incentive structure of academia and industry would have to change radically.

Although they are related, this particular topic encompasses a substantially larger set of issues than the specific motivations for training scientific generalists. Ultimately, it goes without saying that the creation of a new scientific niche would require exploring many practical realities distinct from the intellectual questions related to the structuring of a degree program.

Furthermore, academic incentive structures are receiving substantial attention in light of the reproducibility crisis. Many proposed reforms, such as encouraging the publication of negative results, experiments to validate the findings of other research groups, and the publication of datasets along side research manuscripts, have some overlap with incentive structures that would value generalists. Given how little attention the topic of training scientific generalists has received, I think it is worth more narrowly confining the discussion until the idea has been explored further.

The author regularly makes comparisons between a proposed generalists program and the MD/PhD. However, there is little commonality between the two as both the MD and PhD are independently valuable degrees, and in addition, the MD gives individuals substantial earning potential.

The primary purpose in drawing a comparison with MD/PhDs is to give an example of a substantial intellectual challenge that thousands upon thousands of individuals have successfully undertaken. The programs I proposed would be difficult, and the MD/PhD is an example of a fairly heterogeneous training, with multiple hurdles in terms of examinations, and where there is not always a high degree of coherence between the standard medical training and the topic of one’s PhD. Yet many have risen to the challenge of completing the training, if not the ultimate vision of the ideal physician-scientist career.

It is also not intended to be a perfect analogy. A 4-year block consisting of 4 qualifying examinations in different subjects would be considerably different than a 4 year MD. But there is no reason to think that in creating new graduate programs we should confine ourselves to combining pre-existing ones.

Furthermore, the MD/PhD raises an important point that I did not explore in the previous manuscripts. Specifically, the MD/PhD is an example of a long-term institutional experiment, one that required multiple generations of trainees to generate adequate data for analysis. Indeed, in the last two decades there has been a steady stream of articles examining the impact of and in some cases questioning the value of the combined MD/PhD program (Santoro, Mosse, and Young 2007; Suliburk et al. 2008;

Rosenberg 2008; Wilkerson and Abelmann 1993; Sutton and Killian 1996; Ahn et al. 2007; Brass et al. 2010; Zemlo et al. 2000; TJ and LE 2005).

If we were to create programs to train generalists, I would hope that similar analyses would be conducted after a sufficient number of graduates had been trained and given an opportunity to develop their careers. Furthermore, as the motivation behind a generalist PhD program is broader in scope than that of the MD/PhD, it is a rich opportunity to create a diversity of programs whose impact would be examined several decades from now. There seems to be little reason to attempt to arrive at a single consensus program. By its very nature, a generalist PhD should be one with significant diversity.

SOME ADDITIONAL THOUGHTS

In addition to the comments addressed above, I wanted to add several thoughts of my own:

For most PhD students, preparation for the qualifying examination is a stressful period, a rite of passage, and a huge relief when completed. While research poses its own set of personal and professional challenges, preparation for a major examination is typically a more solitary and isolating process. What would be the psychological demands of multiple years of preparation for a series of examinations without intervening periods of collaborative interaction with peers?

One of the primary points of comparison with an MD/PhD is the length of the training and the intellectual demands of the program. There is, however, a significant set of differences worth mentioning. Specifically, medicine provides a highly social atmosphere, and the basic sciences portion of an MD tends to be a hurdle that individuals surmount alongside their friends. Afterwards, clinical rotations are not classroom experiences at all, and nearly every minute of every day is spent interacting with others in a hospital setting.

These aspects of the MD/PhD program provide a social support structure that would be difficult to reproduce outside of the medical context. A program consisting of multiple years of qualifying examinations would be psychologically demanding. It may be that for students capable of handling such a workload, these additional years would be no different than simply a prolonged PhD. Nonetheless, it is an important consideration and one worth examining in greater depth.

The fundamental motivation of the proposed programs to train generalists is to give students an "anthropological" exposure to different fields of science. Is a qualifying examination the best way to accomplish this objective?

I think there is no doubt that preparing for qualifying examinations provides a highly efficient way to master basic graduate level material. However, I have wondered whether qualifying examinations will truly expose students to the culture of different fields, which is the primary motivation of the program. It may be inadequate to master the textbook knowledge without also being immersed in active research in a subject.

This is an issue that requires more discussion- I think there are compelling arguments for either side. One alternative to qualifying examinations would be a series of rotations in different fields, or possibly having a single qualifying examination or set of qualifying examinations of some breadth, but that could be completed in a reasonable amount of time, followed by a series of research rotations in different fields. Another possibility would be for these rotations to be part of a generalists post-doctoral program after the completion of a normal research PhD. There are many possibilities and it is worth generating new ideas and discussing the merits of different proposals.

CONCLUSION

I hope that I have adequately and honestly engaged the comments and criticisms that have been raised in response to my initial proposals. My aim for this manuscript is to clarify any ambiguities in the original articles, as well as to highlight areas of legitimate intellectual disagreement that require additional discussion.

There is, however, one overarching perspective that merits restating. The fundamental context of this set of ideas is to address the complexities of modern science, the consequences for academia, and for those organizations downstream that depend directly or indirectly on research advances. As a historical point, it is worth stating that the most significant set of forces that gave rise to this complexity is the dramatic growth of science following the Second World War. Indeed, even as early as 1949– a year before the creation of the National Science Foundation– eminent scientists Hendrik Bode, Frederick Mosteller, John Tukey, and Charles Winsor wrote about the growing complexities of science and the need for scientific generalists (Bode et al. 1949). Their words are worth reproducing here:

> *The complexities of modern science and modern society have created a need for scientific generalists, for men trained in many fields of science. To educate such men efficiently would require modified courses and new ones. However, a good beginning can be made now with courses which are available in many colleges and universities. One such program is set forth here.*
>
> ***The central problem.*** *Scientific and technological advances have made the world we live in complex and hard to understand. We have today large scale division of labor, complex and indirect methods of production and distribution, large communities and large areas held together by common channels of transport and communication, and operation with small margins of safety, requiring close and delicate control. All of these complex and delicate activities produce scientific and technological problems of great difficulty.*
>
> *Science itself shows the same growing complexity. We often hear that "one man can no longer cover a broad enough field" and that "there is too much narrow specialization." And yet these complexities must be met– and resolved. At all levels, decisions must be made which involve consideration of more than a single field.*
>
> *These difficulties are most pressing in the borderline fields like physical chemistry, chemical physics, biophysics, biochemistry, high polymers, and the application of chemistry, physics, and mathematics to medicine. It is here that both the challenges of the problems and the difficulties arising from overspecialization are greatest. We need a simpler, more unified approach to scientific problems, we need men who can practice science– not a particular science– in a word, we need scientific generalists.*

Sixty-seven years later we have yet to adequately address a set of problems that were visible even before the first national funding agency for scientific research had been created. With this context in mind, I want to state once again that time-horizon of my proposal is the long-term future. It is simply not an attempt to address contemporary issues related to the scientific job market. Just as with the MD/PhD, it will take several generations of trainees before we can fully analyze and understand the consequences of a fundamentally new type of advanced graduate training. This type of long-term institutional experiment is worth conducting and it will not be the first time we have done so. To quote one author analyzing the impact of the MD/PhD,

> *As the 50th anniversary of the initial MSTP awards approaches, it is essential to conduct a full accounting of this program, for which the visibility and institutional cachet far exceed its size. Program directors from the National Institute of General Medical Sciences, the Association of American Medical Colleges, and academic medical centers must lead this effort and establish a database that can be queried longitudinally in a transparent fashion. The health of the US forest of dual-degree programs must be examined without further delay, so that whatever planting, pruning, and planning are needed can be carried out in a manner befitting this national resource. It is past time to look carefully at the trees– as well as the forest. (Rosenberg 2008)*

If the forest of dual-degree programs in medicine alone needs to be examined, what about the forest of the entirety of science? What will such a process look like and have we trained the right type of investigator to even ask appropriate questions? There is no shortage of talented individuals who are

actively working towards contemporary reforms to address critical present-day issues. If we believe that the true beneficiaries of scientific research are future generations and not ourselves, then should we not also value active efforts to reason about how current institutional decisions can impact the long-term future? Programs to train scientific generalists merit serious consideration as a vital factor in sustaining the long-term health of institutional science.

ACKNOWLEDGEMENTS

I would like to acknowledge Joshua Nicholson, David Simic, and Seshu Sarma for feedback on the manuscript.

REFERENCES

Ahn, Jaimo, Christopher D Watt, Li-Xing Man, Siri Atma W Greeley, and Judy A Shea. 2007. "Educating future leaders of medical research: Analysis of student opinions and goals from the MD–PhD SAGE (Students' Attitudes, Goals, and Education) survey." *Academic Medicine* 82 (7). LWW: 633–45.

Bode, Hendrik, Frederick Mosteller, John Tukey, and Charles Winsor. 1949. "The Education of a Scientific Generalist." *Science* 109 (2840): 553–58. doi:10.1126/science.109.2840.553.

Brass, Lawrence F, Myles H Akabas, Linda D Burnley, David M Engman, Clayton A Wiley, and Olaf S Andersen. 2010. "Are MD–PhD programs meeting their goals? An analysis of career choices made by graduates of 24 MD–PhD programs." *Academic Medicine: Journal of the Association of American Medical Colleges* 85 (4). NIH Public Access: 692.https://dx.doi.org/10.1097/ACM.0b013e3181d3ca17.

Rosenberg, Leon E. 2008. "MD/PhD programs– A call for an accounting."*JAMA* 300 (10). American Medical Association: 1208–9.

Santoro, Samuel A, Claudio A Mosse, and Pampee P Young. 2007. "The MD/PhD pathway to a career in laboratory medicine." *Clinics in Laboratory Medicine* 27 (2). Elsevier: 425–34.

Sarma, Gopal. 2016a. "Should We Train Scientific Generalists?" *The Winnower*, January. doi:10.15200/winn.145264.45703.

———. 2016b. "Is There Value in Training Scientific Generalists for Positions at the Edge of Academia?" *The Winnower*, March.

Suliburk, James W, Lillian S Kao, Rosemary A Kozar, and David W Mercer. 2008. "Training future surgical scientists: realities and recommendations." *Annals of Surgery* 247 (5). LWW: 741–49.

Sutton, Jennifer, and Charles D Killian. 1996. "The MD-PhD researcher: what species of investigator?" *Academic Medicine* 71 (5). LWW: 454–9.

TJ, Ley, and Rosenberg LE. 2005. “The Physician-Scientist Career Pipeline in 2005: Build it, and They Will Come.” *JAMA* 294 (11): 1343–51. doi:10.1001/jama.294.11.1343.

Wilkerson, Luann, and Walter H Abelmann. 1993. “Producing physician-scientists: a survey of graduates from the Harvard-MIT Program in Health Sciences and Technology.” *Academic Medicine* 68 (3). LWW: 214–8.

Zemlo, Tamara R., Howard H. Garrison, Nicola C. Partridge, and Timothy J. Ley. 2000. “The Physician-Scientist: Career Issues and Challenges at the Year 2000.” *The FASEB Journal* 14 (2): 221–30. http://www.fasebj.org/content/14/2/221.short.