How to turn USA science degrees into science careers

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This essay discusses the current situation in USA Science, Technology, Engineering, and Math (STEM) higher education. Possible solutions to the current "skills gap" facing an entire generation of young Americans are considered. It is put forth that an "Industry PhD" may be helpful for guiding the next generation of scientists into stable careers in the sciences. Discovery science, wherein one discovers natural laws of the universe, requires a different toolkit than one needs for doing applied science. This is the proposed "Academic PhD" track. Applied science is usually focused around a three to five year targeted plan, with a directly patentable application as the "end product". Discovery science usually takes longer, and is by its very nature uncertain. However, one must discover natural laws before one can apply and patent them. Both "Academic PhD" and "Industry PhD" tracks are required for healthy economic growth in industrial nations.

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Introduction

While top-ranked graduate schools in the US have high rates of acceptance for international students, fewer and fewer US citizens with four year BA's and BS's in STEM subjects gain admission. Many of these US students attend large public universities to earn these undergraduate degrees, as these institutions generally have relatively low tuition costs.

At larger institutes renowned for particular graduate programs the focus for professors has been shifted from teaching undergraduates, to mentoring Master's and PhD students through scientific publishing. The undergraduate degrees earned from these research-orientated universities do not give students job skills required for even entry level STEM positions (such as a laboratory technician). Frequently, a Master's is required for these entry-level jobs in scientific markets like biotechnology and bioengineering.

This is due in part from the sheer amount of scientific advancement that has been accomplished even within the last 20 years. There is more to learn now than ever before, and this results in longer time requirements for earning graduate level STEM degrees.

The focus on education has shifted from undergraduate to graduate at the large, inexpensive universities. The legions of Bachelor's STEM students churned out by these institutions are prepared for neither a US graduate school, nor a "science job" with career prospects. Many USA graduate schools are forced to admit highly qualified international students over students from their own undergraduate programs. This further exacerbates the problem of USA youth unemployment.

Notably, several EU countries such as Germany have highly efficient job-to-work programs that provide the labor force for their significantly expanding manufacturing and engineering based economies. Companies that require workers with extensive technical training can apply for government funds. These grants give free or low-cost student stipends, and the young student is paid to do technical internships that increase their education and skills.

These programs are already mimicked by some US universities. If implemented more widely and standardized, similar programs might provide the nation with a new, young and educated workforce for the rapidly expanding, global STEM economy.

Why the USA Professors Aren't Teaching Undergraduates

The US higher educational system at an undergraduate level is losing value. Wealthy students can in essence "buy their degrees". This results in high grade inflation and lower standards at public universities in the science, technology, engineering and math (STEM) undergraduate degrees. At larger (ca. +25,000 students) public universities, enormous lecture courses are taught for hundreds of paying undergraduates.

While the Professor gives the 45 to 60 minute, two or three times a week lecture portion of the course, the students spend more time learning from the Teaching Assistants. TAs are usually graduate students with a four year Bachelor's degree that have been accepted as members of a graduate school within the university.

By teaching the undergrads the TAs earn their "teaching credit" required for completing a Master's or PhD degree with a graduate school. Many of these large public universities have high quality graduate schools, but do not focus on teaching at an undergraduate level.

Instead of actually teaching undergraduate level courses, many STEM professors must "publish or perish" to ensure federal funding is granted to their labs. Much of a professor's time is spent with their gradate students and postdoctoral scientists, working to ensure timely submission of papers, dissertations, and grants.

The US federal government has many granting opportunities that fund 5+ year contracts to pay for a student to work through their Master's and PhD degrees. (The students usually earn a little above cost of living for the particular US

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city or town.) The grant will also fund any lab equipment needed to test the hypothesis (within reason). This usually comes to a few million dollars per professor, distributed over three to five years.

This money is managed by a fleet of departmental and graduate school administrative assistants, a secretarial workforce that frequently has better job security than the younger professors. As the money is granted to the professor and not the school, the professor can leave the university if they desire and take the money to another institute. (This is, of course, usually frowned upon.)

Grants can also be written between many departments within the university, usually to purchase large and expensive state-of-the-art scientific instrumentation. This equipment shared by the professors within the departments. These professors can easily share students with other member of the department who want to learn cutting edge cross-disciplinary research from two different professors.

As the US federal budget is much larger than any State one, universities in the States compete with each other for scientists that can write these long term research grants. Professors that are able to provide the university with a stream of federal money for graduate students, postdoctoral positions, and equipment are highly valued no matter how young or old they are. Many professors are not required by their universities to teach the larger lecture courses, unless the professors are "between grants" and need a few months of funding.

Instead of teaching undergraduates, they are expected to publish in high ranking journals like JACS, PNAS, and PRL. These articles usually highlight part of the dissertation for a particular PhD student. PhD candidates are chosen by their professors after careful interviews of the entire graduate class. The federal granting agencies tracks the students, and thus its investment in the student's "science education quality", through the independently peer reviewed journals.

Thus, for admittance to graduate programs in the States, the professors are looking for only the most talented scientific minds of the generation to guide through the process of publishing in international scientific journals. These young scientists are "kept track of" in the established scientific literature.

The research professors can have large labs, but most try to keep the number of PhD and postdoctoral students low so they have time to personally guide the students though the current scientific literature in their fields. Particular labs where the professor is known for publishing at high rates are very difficult to get into as a PhD student, even once within the graduate program.

The limited number of spots and high number of applicants drives up competition, and this selects for students capable of handling the rigors of peer review. Due to these time commitments to higher-level students, the science courses in these public universities at an undergraduate level are not really "taught by the professor". This results in young science students with four year degrees that are unqualified for the graduate school of the very university that gave them an undergraduate education.

International STEM Undergraduate Educations Feed Directly into STEM Jobs

These undergraduate students at large US universities struggle to compete with international students on a global level for admission into STEM graduate schools. Other nations have invested their tax money in a good, free, and early education in STEM for their youth.

US funded graduate programs are flooded with competitive international students who work hard in the lab, and want to work with the best professors in the world for their higher educations. As one Lithuanian student getting a four year Bachelor's in Biophysics said, "We get a very strong, Soviet-style eduction in math; and we get it very young". Once trained, these people can get a good job in the US in industry, but many go home and use their higher education to

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bring benefits to the country of their birth.

Germany is a country known for its strong tradition in education for skills such as engineering and medicine. Indeed, their young students are frequently admitted to the best science higher education programs in the world. This is perhaps due to the long history of skilled trades, guilds, and Mastercraftsmanship from the Middle Ages. These organizations are still alive in parts of the German government and economy; and are know for having intricate and secretive hierarchical structures.

In contrast, the US STEM graduate school system was born out of the Manhattan Project and refined in the cold war as a method for giving the best weapons technology to the military. Ultimately, for a US science academic career, the law of publish or perish rules with an iron fist, resulting in globally competitive innovative research.

However, the system does not generally guarantee a tenured position for the young professor. In contrast, for a European academic career, the emphasis is upon acquiring a strictly defined set of credentials and qualifications which earn you the qualifications needed to teach at various levels in the STEM fields.

STEM Education: the International Approach vs. the US Approach

These rigorous qualifications for academic positions in Germany are deigned to ensure high quality of teaching for young STEM students. Unfortunately, the lengthy time requirements for earning these qualifications can serve to keep younger scientists out of higher level academic positions within university faculties. Additionally, the habit of "inheriting" academic leadership positions, and the funding they come with, serves to keep young scientists with scientific leaders to learn from them how to manage the projects.

Leaving to gain experience with a different professor is less encouraged, but the long-term experience gained does result in strong teaching careers at the university level. Unfortunately, younger scientists can get trapped in lower ranks at universities, with little opportunity for advancement. As one science postdoctoral student in Germany put it, "In European Labs, you always apply to The Boss". This is in contrast to a US graduate school system, where you choose a professor to work with after you are admitted to the graduate program.

Progression up European academic ranks seems to be linked more with age and time spent on traditional projects with a particular, well-established professor. The German Prof.s are excellent at applying innovations in a lab, and moving quickly to efficient product production. This likely arises from the apprentice/journeyman/master system that quickly gets highly trained students good jobs in science industry.

However, their government is mostly interested in funding science with direct and immediate economic applications. Prof.s are frequently so busy managing many different short term projects, that PhD and postdoctoral students rarely see them. They are not coached though the global standards of independent scientific peer review, which is the basis of any high quality PhD. This unfortunately serves to dampen the mobility of young scientists up the ranks, since they must serve under a Prof. for many, many years to earn the right the take over an authority position.

The US system, meanwhile, results in professors that are good at writing grants that fund five year scientific endeavors. (However, these professors tend to be "Ivy Tower" types and not as good at "immediate economic applications of the science".) It is perhaps unfair to compare the two graduate systems past a certain level, since the States have a much bigger federal budget to spend on state of the art scientific research than any single European country.

There are scientific institutes in Europe (such the Max Planck Institutes of Germany) where principle investigators may have smaller labs to concentrate on publishing in the leading journals

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like Science or Nature. Unfortunately these are not connected with an underlying administrative structure like the US-style Graduate Schools funded with undergraduate tuition fees, making it difficult for students to switch projects if they decide to work with another professor.

However, for German students, you're either selected at a very young age for fast-tracked science training and lifted up to an Institute, or you must try and go through a university PhD system more concerned with placing you with a good company job than with getting you published. The PhDs earned in some of the STEM fields at some German universities are more like certificates, in particularly for readily applied sciences like Chemistry or Biology.

The German government pays the Prof. upon completion of a student's PhD degree, and the student is not tracked further. This stands in stark contrast to higher levels in US academia, where the only thing that matters for your getting hired as a professor at a university is your "academic lineage", and students are carefully tracked by their undergraduate and graduate administrations.

(This is not as true for getting a position in the USA science industry. Industry jobs frequently pay better than professorship positions, are more stable, and scientists are not expected to publish. On the other hand, they usually make you wear a suit to work, something that does not sit well with many academically inclined minds.)

Outlook

The US graduate academic system is good at producing professors whose science measures up to the global standards of publishing papers. Under the shelter of the university system, talented young professors can write publications for high ranking scientific journals using funds from the federal government. The university has grant managers departments, where legions of administrators handle the money brought in by the professor's federal funding, as well as money from any patents that result from the investigation. In some ways, professors are treated as small independent business owners in whom capital has been invested. They are permitted to hire and fire students within their own lab, and are expected to participate in faculty meetings to help established professors ensure the department continues to produce world-class scientific research.

However, the US graduate schools should perhaps recall that not everyone wants or needs to be a world-class scientist. They could stand to emulate the strong German tradition of applying scientific discoveries for direct economic benefit and the creation of stable, long term science jobs that will need Master's level lab qualifications. Meanwhile, the German universities and funding agencies might want to think less about short term economic benefits derived from scientific discovery, and allow greater flexibility for their STEM students to work on their own projects. That is, if their economy can afford to let their young scientists work at a university rather than a company.

To help increase the quality of USA undergraduate STEM educations, more qualified "teaching scientists" should be hired by the large public universities to help the grant-writing professors both teach and recruit students at young ages. These students could then be directly admitted to the graduate program, where they would have several clear career tracks. One track would allow STEM students to pursue academic publishing if they desire, while also acquiring the skills to teach and grade at an undergraduate level. Another would provide a track for developing the skill sets needed for working in science industries, and the student would earn an "Industrial" Master's or PhD. Several programs incorporating industrial experience into the degree have been started in the States. However, the idea could use funding at the federal level to compliment industrial investment in education. Ideally, the student could be transferred directly into a job or career with the company they trained with and provide a return on the investment.

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Many large US universities are already converging on this solution. They could use federal support to ensure enough teachers are hired to focus on the undergraduate students, and to continually develop a standard curriculum relevant for skills required in current STEM jobs. This would enable the US students to gain the lab skills they need to apply to Master's programs after their four year undergraduate degrees. After a year or two in the graduate program, the student can make an informed choice about whether they would like to continue doing academic research and publishing, or transition into a career in industry. Meanwhile, those that would prefer to "get a real job" immediately can graduate and enter the workforce at a technician level. They can also stay in the program and do an industry-track PhD, and gain the corporate business experience many STEM companies need in their management levels. (See flowchart for outline of the different graduate tracks.)

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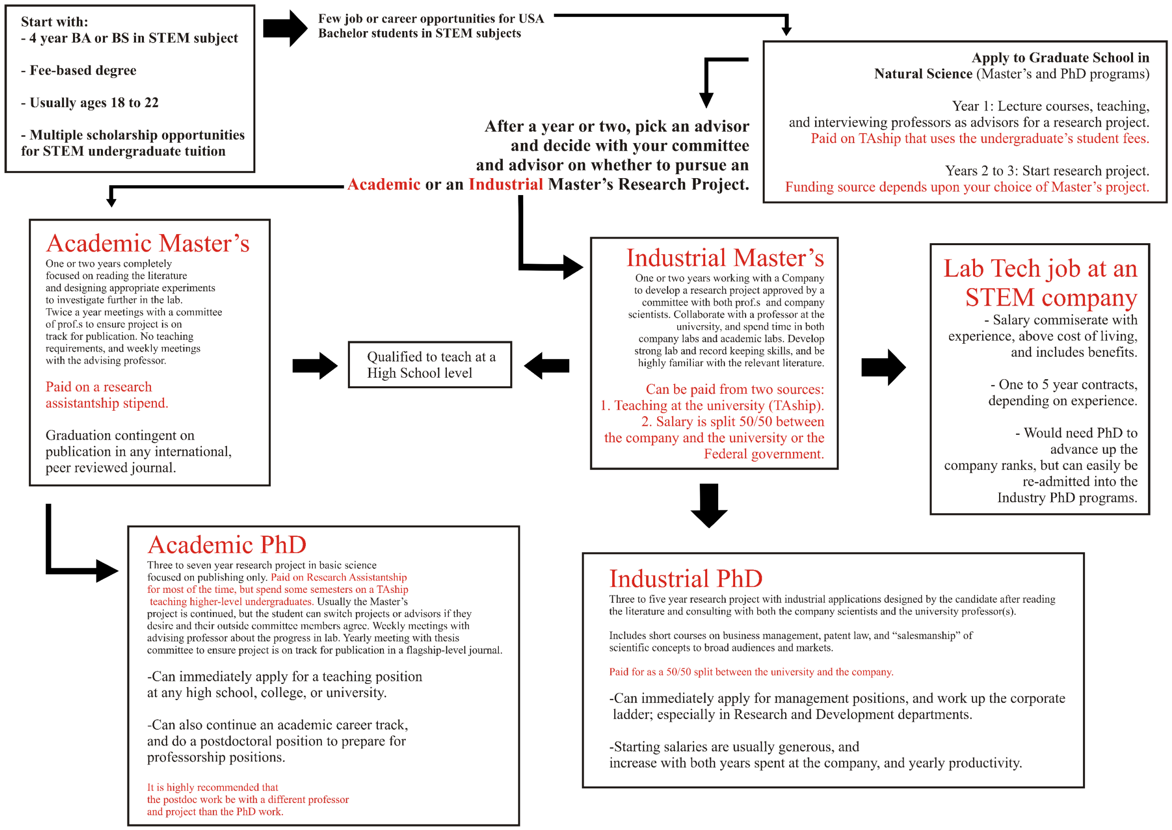

Figure 1 – Flowchart for academic and industrial PhD and Master's tracks, starting with a four year Bachelor's degree in a STEM subject.

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