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*Values and Science for the 21st Century**

Abstract

Science is often misunderstood by the public, including many educated people. It has been seen as the undisputed solver of mankind's problems, including social problems, as a source of danger for the world and society, or criticized as overrated or failing to live up to expectations. There are enough real cases to support different views, as well as historical examples of periods of pro-science and anti-science. Meanwhile science itself is typically seen in terms of its outcomes, its knowledge products. What is remarkable, though, is the process of science. Science is a unique social system oriented towards finding truth, in the form of reliable knowledge. This social function of science is supported by a particular set of organizational arrangements and guidelines for research which at the same time emphasize creativity and criticism. But this system can only work as long as it is not corrupted. The social system of science is easily affected by pressures from outside, especially political and economic ones. What is needed is a way to safeguard science as a space for open discussion and critical deliberation. Science may be the place to defend a set of core academic values for the 21st century.

Science as a unique truth-finding system

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What is remarkable, though, is the *process* of science. Science is a unique social system oriented towards finding truth, in the form of reliable knowledge. This social function of science is supported by a particular set of organizational arrangements, norms and practices which at the same time emphasize creativity and criticism. But this system can only work as long as it is not corrupted. The social system of science is easily affected by social pressures, especially political and economic ones, and these forces sometimes threaten to change the very premises of doing science. Unlike many other systems, science is oriented around truth and trust rather than power. This makes science quite unique in today's world.

Science as a collective process

What did it take to have science at all? Academic science as we know it is a product of a long development and many struggles against authorities of various kinds. But there were certain principles that early scientific practitioners realized had to be in place. One was the importance of sharing knowledge. The whole idea of truth as something that could be based on experiments or observations rather than book knowledge was in fact quite a radical idea at the time. But the truth could not be left to the individual scientist – others would have to verify this truth. This was one of the rationales for the early scientific societies, whose members often staged public demonstration experiments, so that everyone present could see with their own eyes what was happening. But the really important point was that knowledge was being shared and made public.

This was totally different from the earlier secrecy of alchemy, where recipes passed from master to apprentice or between close colleagues, in the form of allegoric stories or mystical symbols. That knowledge got its value exactly from being hidden and proprietary. Science encouraged the absolute opposite: It actively put a reward on making knowledge public. The strategy was to grant priority to the first person to publish a new scientific finding. Meanwhile the reward for making this new information public was not to come in the form of money, but rather as recognition from other scientists for scientific eminence. This was a quite unusual arrangement.

Making knowledge public allowed others to build on it – but also to check its validity. Science is in fact a very clever system which has developed a whole structure of mutual checking methods, such as refereeing of manuscripts submitted for publication and replication of experiments. Science expects individual scientists to be dedicated and honest, but it also realizes that they can make mistakes. Scientific truth therefore does not rest with the input of an individual scientist, but is the final outcome of a collective process (a process which actually continues over generations). Still, even with these control systems in place, science counts with the individual scientist to do his or her best to produce as reliable information as possible. This is why a scientist is expected to be dedicated to the pursuit of true knowledge, not being affected by other interests that could get in the way of the goal of truth.

This is the premise of academic science as we know it, and this has been the basis for science's contract with society. Society has agreed to support basic science, expecting to obtain reliable knowledge and the education of the next generation in return.

From public to private funding

But after World War II the picture largely changed, with the coming of Big Science. Watson and Crick's unraveling of the structure of DNA in 1953 was one of the last examples of „little science". The post-war period was the time of the establishment of the National Science Foundation and the United States' governmental grant policy, which promoted research in pure science under Vannevar Bush's slogan „Science the endless frontier". The general vision was that the results produced by basic science would later be turned into useful applications. The realms of pure and applied science were connected, but operating on different tracks.

This whole relationship changed with the discovery of the so-called „recombinant DNA" (gene splicing) technique in 1973, which soon gave rise to the lucrative biotech industry, with American university professors founding startup companies for their genetically engineered drugs and other products. Meanwhile, as the US government was running out of money in the 1970 s, a surprising new grant policy emerged at the National Science Foundation. Totally deviating from the earlier „linear model", which had industry waiting to apply the products of pure science, academic researchers were now asked by NSF to actively work together with industry sponsors to make sure that their research would be relevant to commercial goals. American industry, in turn, had realized that new scientific knowledge would be the motor in the emerging knowledge economy. In 1980 the final obstacles to the commercialization of university science were removed with the Bayh-Dole Act, a landmark legal decision which allowed scientists supported by government grants (that is, taxpayers' money) to profit from patents on their discoveries. This opened up the possibility of large scale patenting and licensing for universities. [1]

And later of course, with the sequencing of the human genome came a whole new industry of genetic testing and manipulation, which raised additional ethical questions.

What also happened with the boom of biomedical research, however, was an upsurge of scientific fraud. [2] This was quite unexpected, because it so blatantly contradicted the assumption of honesty and trust that underlies science. The scientific community and the universities initially had a difficult time responding, because there were no guidelines for how to handle fraud. As these were being discussed and developed, the very ability of the scientific community to police itself was being questioned by Congress. Lack of clarity about the meaning of fraud and misconduct caused the famous case around Nobel laureate David Baltimore to drag out for over a decade. [3] After much wrangling, guidelines for how to handle suspected fraud were agreed upon in 1992 by the three highest research authorities in the country: National Academy of Science, National Academy of Engineering, and Institute of Medicine. The guidelines were further refined in 2000. [4, 5]

There have been some serious problems with bringing in a commercial model to the universities. Commercial science operates on different premises than academic science. Such things as public knowledge or academic freedom are not core considerations for industry. Among the more obvious problems with industry-sponsored projects have been publishing delays, data withholding, and outright suppression of research findings. Moreover, there are cases where university researchers wanted to report important findings of direct relevance to public health but were prevented by companies connected to their universities. [6]

A more subtle criticism is that commercial sponsors may discourage certain research questions from being raised at all. Or some companies may directly affect the academic program itself – this has become a problem especially in medical research. The education of students gets affected as well. It is difficult to be at the same time an academic mentor and run one's own company. In some cases professors have even been using student research to develop their companies, which has resulted in difficulties for students to publish. This has sometimes led to lawsuits. [7] Also, allowing universities to patent their own research results easily encourages too broadly based („greedy") patenting and allows too little space for knowledge that can be shared and built on by other scientists – that is, public knowledge.

Of course academic science and commercial interests do not necessarily have to be in competition. The current crisis may simply be an outcome of a situation that got out of hand. For instance, academic and traditional Research and Development science have coexisted from the 1960 s, despite their quite different organizational structures and cultures. It is the recent opportunistic mingling of academic and industrial science and the lack of clear guidelines that has created the present problems. An obvious solution is better coordination and oversight of some kind. For instance, there is the idea of establishing a non-profit technology transfer bureau at the federal level, staffed by experts. In this way it would be possible to move the patent licensing activity away from the hands of individual universities and their technology transfer offices. The federal experts would also be able to help identify and develop embryonic ideas and, working with private investors, bring promising academic discoveries to market. [8]

Consequences of the commercialization of science

Meanwhile, what is going on? Is the whole culture of the university changing? Is it so that science can no longer serve the public interest? Arthur Relman, famous former editor of *The New England Journal of Medicine,* already in 1980 warned about a new „medical-industrial complex", where research is getting increasingly done by companies rather than universities. This results in changes in research protocol and the employment of less trained personnel, while the actual experts are at the universities. [9]

Others have pointed to more profound changes for science itself. Some envision a future of global interdisciplinary expert teams forming and dissolving around particular problems. What happens to the accumulation of such potentially valuable knowledge? It does not build a disciplinary structure. This means that the quality of this new science will not be assessed by experts in the discipline, because there is no discipline. In other words there will be no traditional, field-specific standards for „good science". Neither will individual scientists be rewarded with recognition for intellectual contributions. What counts instead are management skills, and the measure of success will be the ability of getting projects or grants. The research problems chosen will not be internally generated, but decided by outside forces. [10, 11]

Is there anything good to be said for the involvement of universities with industry? Actually, there is. Industry can provide internships and training for students. It can stimulate creativity by suggesting real problems for university student teams to solve. There is a real world out there, and students do need to learn various skills on top of their academic ones. At my own university, Illinois Institute of Technology (IIT), we have introduced inter-professional group projects (IPROs) in parallel with traditional academic engineering education. Students develop teamwork and leadership skills, learn project management, and get used to inter-professional and inter-cultural collaboration. Some of the real world problems that students work on are suggested by industry, many ideas come from the students themselves or faculty.

Another advantage is that companies, unlike governmental agencies, may be willing to sponsor risky research with uncertain outcomes. Governmental funding agencies simply cannot afford to support the type of scientist who operates on the edge of creativity. A 2007 Nobel Prize winner recently described how difficult it was for him to get funded for what was to become his breakthrough research on gene targeting. Indeed, the review panels that assess governmental grant proposals are typically looking for „safe" proposals, ideas that are understandable within existing science and likely to produce immediate results. [12]

Ironically, even proposals under a brand new category, „transformative research", which was recently created at the National Science Foundation exactly to accommodate people with would-be path breaking ideas, would have to be structured in a quite traditional manner. (This was, interestingly, admitted by the directors themselves in a lively discussion following a lecture I gave to NSF on the special challenges faced by highly creative scientists). [13]

There is a lot of tension today as many universities believe that they should follow a company style business model. Universities today are facing hard economic realities and want engage in partnerships with profitable companies. Many in fact try to attract businesses by building new research and technology parks where their faculty and students can work. At my own university I have a colleague who in our University Technology Park has his university lab on one side of the corridor and his biotech company lab on the other side. He claims that he is able to change his head in the middle of the corridor, and that the students in his university lab do not interact with the students in his company lab or use the instruments there. The corridor, though, is very narrow…

In defense of academic science

We in the universities and academies who see our primary mission as being that of educators and scholars have to carefully examine how some new arrangements might be actually undermining the very idea of an academic education, and the very meaning of being a scientist. We need to stand up for the extreme importance of preserving the values and norms of academic institutions, and the attitudes that uniquely prevail there. The existing system, developed over a long time, is one of our few – perhaps the only –cultural model of rational discourse based on open discussion and criticism. Such a model has clear importance for democracy.

A central aspect of academic science is the transmission to a new generation of the essential core of a scientific discipline, including its tacit knowledge. But additionally what is transmitted in this way is the fundamental *scientific attitude* – the emphasis on honesty and openness and orientation toward impartial truth. That attitude has to be supported, and the only place for this is the traditional academic setting. It will become increasingly important to fight for the maintenance of the existing academic structure in the face of growing pressure for a business model of the university. The view that universities should become some type of profit-making companies undermines the whole idea of academic institutions and their educational mission. Universities cannot be run as companies and students cannot be regarded as customers.

A crucial point in academic science is that a person's „capital" is of a symbolic nature – it comes in the form of recognition for intellectual achievement, such as prizes and medals, or having a law or constant named after you. Or even a measure (an Angstrom). The best reward for a scientist, though, is to have his or her contribution live forever. And this is why it is in the scientist's own interest to be as honest, careful, and correct as possible.

Interestingly a scientist's overall academic reputation does not only have to do with his or her contribution to knowledge. Letters of recommendation often seriously consider also such things as the „character" of a scientist. This is important in an institution that relies so much on trust. Academic science has a certain implicit moral infrastructure of norms and expectations for proper conduct. This moral infrastructure works together with science's various systems of mutual checking to provide the larger society with reliable information. If academic science disappears by getting overwhelmed by too many outside interests – commercial or political – society will lose its most important instrument for truth finding, and its best model for impartial pursuit of knowledge.

There are some signs that academic science is strong enough to resist the commercialization trends. A recent Finnish study reported how university researchers, who wanted to continue in academia while also producing commercial products, got involved in so many conflicts, also with their students, that they ended up leaving academia altogether. [14] In Europe especially, the academic and commercial cultures may not mix well together. And there are individual researchers who refuse to play the patenting game and put up information on the internet for everyone to use.

I am cautiously optimistic, however. I believe that just as it was with the upswing in scientific fraud in the late 1970 s and 80 s with the rise of biomedical research, we are now seeing a boost in commercialism for some time to come. But in the end, there will be countermeasures and adequate controls established. Academic science will be able to snap back closer to its core. Why is this? The reason is that academic science is science as we know it and value it – there *is* no other type of science, if we define science as an institution that is devoted to, and rewards, practices that aim at separating truth from falsehood. No society can afford to be without this type of institution.

We in the academic world have a special responsibility to safeguard science as a space for open discussion and critical deliberation. Science is an important repository for core academic, moral and democratic values, for the 21st century and beyond.

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