Open Hardware and Scientific Autonomy in Germany: How Transfer Activities Can Become More Attractive

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Erstveröffentlichung / Primary Publication
Konferenzbeitrag / conference paper

Empfohlene Zitierung / Suggested Citation:
Voigt, M. (2023). Open Hardware and Scientific Autonomy in Germany: How Transfer Activities Can Become More Attractive. In B. Herlo, & D. Irrgang (Eds.), *Proceedings of the Weizenbaum Conference 2022: Practicing Sovereignty - Interventions for Open Digital Futures* (pp. 94-103). Berlin: Weizenbaum Institute for the Networked Society - The German Internet Institute. https://doi.org/10.34669/wi.cp/4.9

Proceedings of the Weizenbaum Conference 2022:
Practicing Sovereignty. Interventions for Open Digital Futures

OPEN HARDWARE AND SCIENTIFIC AUTONOMY IN GERMANY

HOW TRANSFER ACTIVITIES CAN BECOME MORE EFFECTIVE

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KEYWORDS

open hardware; open science; knowledge transfer; technology transfer

DOI: 10.34669/wi.cp/4.9

1 INTRODUCTION

Technology is a fundamental instrument of human action. Those who develop and distributes it therefore have a major influence on the way we act. Hardware plays a central role in digital technologies as it is also the basis for all software. Since industrialization, knowledge about hardware has migrated more and more into the hands of the very few—through the division of labor and industrial processes. This has created dependencies (Simondon, 2012). With open hardware, people all over the world want to counteract this development and make technology more participatory. The aim is to make hardware understandable, repairable, and changeable. This includes open design, freely licensed documentation and project files, and the use of standard parts.

Science should play a central role in this context. Because universities generate knowledge financed by the publicly funded system. Scientists working on publicly funded projects are also engaged in hardware development, which is the basis for numerous innovations around the world that improve science itself. This makes them part of the innovation system, which should be accessible without barriers.

So, universities have the responsibility to transfer knowledge, an activity that has become increasingly important (Siegel & Wright, 2015). Many institutions make knowledge transfer requirements explicit in dedicated transfer strategies. The focus is on the dissemination of scientific knowledge to "society." Universities operate knowledge transfer offices for this purpose. However, they often miss their target. The notion of society is often narrowed down to economics. And transfer activities are often limited to start-up consulting and patenting activities (Nilsen & Anelli, 2016).

Open access and open science hardware are elementary factors in sharing knowledge more widely and effectively. They also form the basis for more autonomy in science. The present article will show this by means of examples. In addition, it will review aspects of a reformation of transfer offices. On this basis, university institutions can fulfill their responsibilities, increase the sustainability of research projects, and contribute to distributive justice.

1.1 WHAT IS OPEN SCIENCE HARDWARE - A SHORT DIGRESSION

Open hardware, often known as open-source hardware, is a technology-transfer approach in which hardware designs are made publicly available online for anyone to use, alter, and commercialize.
The often-quoted definition of the Open Source Hardware Association states:

> The hardware's source, the design from which it is made, is available in the preferred format for making modifications to it [...] Open-source hardware gives people the freedom to control their

technology while sharing knowledge and encouraging commerce through the open exchange of designs.[22]

Any piece of hardware used for scientific research that is available for purchase, assembly, usage, study, modification, sharing, and sale is referred to as "open hardware for science." It consists of both standard laboratory tools and auxiliary supplies such as sensors, biological reagents, and analog and digital electronic parts.

2 POTENTIAL FOR SCIENCE THROUGH OPEN SCIENCE HARDWARE

Around the world, there are committed scientists who advocate for open hardware in the science system. One network that has become known worldwide is the Gathering for Open Science Hardware network. People are committed because science itself often depends on technologies that have been specifically developed during the research process itself. Scientific measurement instruments are one example. They are often developed as part of research projects. Scientists involved then set up a company and sell the instruments back to scientific institutions. In this way, the knowledge about the instruments disappears from the institutions and dependencies arise. Service contracts may arise as a result, and while they can have advantages and save money (Wang & Richardson, 2020), they can also become problematic in the long run.

One example of this arises when companies go bankrupt or take products off the market, which often happens when company business models focus on servitization (Neely, 2008). Purchased devices then become unusable, because all the information and spare parts come from the manufacturer. A particularly tragic example of this arose in the field of biotechnology—the manufacturer Second Sight Medical Products withdrew its retinal implants from the market and people who had the implant in them had no way to maintain them.[23]

Another side of this issue is that such services are unaffordable for facilities in countries with lower socioeconomic development. As a result, they are unable to repair and maintain the equipment. "The World Health Organization estimates that 70% of donated medical equipment in sub-Saharan Africa is out of service" (Arancio & Shannon, 2022). Closed, outsourced technologies thus inhibit development, understandability, and reparability. In addition, they give rise to barriers that deprive socioeconomically disadvantaged countries of development opportunities. In contrast to proprietary approaches, approaches that develop such tools as open hardware have many advantages. There are numerous examples already.

[22] https://www.oshwa.org/definition/
[23] https://spectrum.ieee.org/bionic-eye-obsolete

2.1 AUTONOMY & COST SAVINGS THROUGH DEVELOPMENT OF OPEN INSTRUMENTS

Full-featured commercial systems are frequently unnecessary for those of modest means; instead, a straightforward open hardware solution could be adequate or even better. This is particularly true for lab instruction, where employing stripped-down open hardware may more effectively explain the fundamental measurement techniques than a closed-box commercial product. Open hardware's lower cost may also make it possible to give equipment on a "one-per-person" rather than "one-per-class" basis, improving the learning environment for students (Mello, 2020).

2.2 SUSTAINABILITY THROUGH COMMUNITY BASED DEVELOPMENT

Often, scientific projects end when public funding runs out. Open-source publication and community building can help to prevent this. "The long-term sustainability of a project such as [OpenFlexure] depends on the formation of a community, which is now active on the project's repositories on GitLab.com. As well as questions and bug reports, we have had contributions with fixes and improvements (...)" (Collins et al., 2020).

2.3 EFFECTIVE KNOWLEDGE TRANSFER AND INNOVATION PROMOTION

Experienced research institutions like CERN that have been publishing their knowledge and technologies open source for years have achieved much better reach for their transfer activities. In addition, they have also succeeded in stimulating innovations. As the following quote indicates:

> The Open Hardware Repository currently hosts more than 100 projects, ranging from small projects with a few partners to bigger projects with multiple contributors from both industry and academia. A dozen companies are actively involved in projects in the Open Hardware Repository, and some produce the physical hardware for CERN and other customers. CERN plays an important part also as a pilot customer for the hardware, legitimising the quality, making it easier for companies to sell it to other customers at a later stage. The Open Hardware Repository has led to an unprecedented re-use of existing design among scientific collaborators and internally at CERN. (Nilsen & Anelli, 2016)

2.4 EASIER ADAPTABILITY AND REPRODUCTION THROUGH MICROCONTROLLERS

The capacity to control and automate hardware is now more accessible than ever thanks to the development of robust-yet-user-friendly microcontroller and microprocessor platforms. The work of the instrument developer can be significantly simplified by the wealth of built-in capabilities included in modern microcontroller development boards. Timer functions for precise task scheduling, analog-to-digital (ADC) converters for reading analog input signals, digital-to-analog (DAC) converters for creating arbitrary voltage waveforms, and hard-wired digital communication protocols for quick data exchange with other digital hardware are all useful features. Frequently, affordable add-on boards can be used to add missing capabilities regarding signal conditioning, motion control, wireless communication, and audio or image processing. This shifts functionality from the hardware to the software, thus simplifying the replication process (Mello, 2020; Fisher & Gould, 2012).

3 Challenges in the Establishment of Open Science Hardware

3.1 Open Hardware is absent from Open Science strategies or definitions

Despite numerous advantages of open hardware in the scientific context, there is still little development in this area. This becomes particularly evident when looking at various open science strategies published by scientific associations in Germany, like the *Wissenschaftsrat*.[24] Here, terms like "open-source hardware" do not even appear. Patents are also completely left out, even though they are an essential part of the scientific publication system. The German federal government even explicitly excludes patents. "The decision to exploit results commercially, e.g., by patenting, also remains unaffected."[25]

This shows how little attention is paid to open hardware and patents, even in the open science scene. This status is probably based on the proximity to economic interests pursued through technology transfer and an associated culture of intellectual property. A rethink is needed here, because, as will be shown in the following, technology transfer succeeds when it is pursued with open concepts.

3.2 The problem with university patents

A challenge is the law on employee inventions in Germany. If employees have discovered something usable, they must report it to the responsible person at their research institution. This person then has the right to apply for a patent. Otherwise, the right is forfeited to the developer. A lot of resources go into this process. The aim behind this is to enable research institutions to attract third-party funding by entering into licensing agreements or selling the patents. For some institutes, the commercialization of their research is a way of obtaining extra income for the institute (Bray & Lee, 2000). However, more importantly, it is a way of strengthening the institute's attractiveness and role

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[24] https://www.wissenschaftsrat.de/SharedDocs/Pressemitteilungen/DE/PM_2022/PM_0222.html
[25] https://www.bmbf.de/bmbf/de/forschung/digitale-wirtschaft-und-gesellschaft/open-access/open-access_node.html

in society. In addition, patent applications influence institutions' and individuals' reputations (Leitch & Harrison, 2005). The patent process is a major barrier to knowledge transfer and open science hardware, first, because the process ties up numerous resources, and second, because patent publications impose strong limits sharing and developing patented knowledge resources. There is the possibility of making patents compatible with open hardware, but this would require a fundamental change in the goals behind current practices.

A look at the figures shows that a rethink is needed. Patenting scientifically generated technologies is not sustainable, because most university patents do not even cover their costs of around €43,000 (Krause, 2017). Moreover, publications on university patents conclude that the supposed positive effects on society would likely have occurred even in the absence of patenting. "With the positive side effects described [in relation to society], however, it can be argued that the effects may also occur when inventions are published by universities but not patented. A causal link with the decision to apply for a patent for the invention is difficult to clearly establish" (Krause, 2017). Thus, the patent has no significant effect, but costs a lot of money.

These facts do not just apply to Germany. Even the USA, which is often cited as a positive example of scientific resource patenting, does not manage to monetize patents to any significant extent. Here, too, the positive effects are absent. "The results of applying this methodology to an average research university in the U.S. showed that it is not economic to invest in IP protection and patents." (Pearce, 2022). One study found that only 16% of knowledge and technology transfer offices in the United States were self-sustaining (Abrams et al., 2009).

4 OPEN HARDWARE AS AN OPPORTUNITY FOR TECHNOLOGY TRANSFER

The above-mentioned aspects show that there is a need for a rethink of the transfer activities of research institutions. Although it is common practice for universities in the United States and Germany to have transfer offices, it is not economically rational to continue to support them with their current alignment. "Instead, to increase the economic bottom line of the university as well as increase the good that university research does for society, universities should open source all their innovation." (Pearce, 2022)

4.1 THE ROLE OF TRANSFER OFFICES

Knowledge and technology transfer offices have been created in most universities and research centers to manage the dissemination process (Siegel & Wright, 2015). The activities focus particularly on obtaining third-party funding and building reputation. Revenue generation is only a part of the picture, and knowledge and technology transfer offices have been found to increase access to external funding, to promote innovation and entrepreneurship, and to contribute to other public benefits (McDevitt et al., 2014). However, there are several ways in which this can be done successfully while simultaneously benefitting transdisciplinary communities and socioeconomically disadvantaged actors in addition to economic actors.

In this regard, Upstill & Symington (2002) argued that there are three basic modes for technology transfer from public research to the business sector:

- Noncommercial transfer: seminars, informal contacts, publications, secondments, and staff exchange and training
- Commercial transfer: collaborative research, contract research, consulting, licensing and sale of intellectual property and technical services
- New company generation: direct spin-offs, indirect spin-offs, and technology transfer companies

Noncommercial transfer, such as publications, presentations, and informal exchanges, have been found to be among the most important ways to diffuse public research to industry (Cohen et al., 2002). Even in institutes known for their large patent output, such as MIT, publications outnumber patents as a mean of transferring knowledge (Agrawal & Henderson, 2002). To increase the impact of their research and developments, organizations should make their knowledge available free through open-source licenses and other open mechanisms (Sorensen & Chambers, 2008). CERN, as one of the leading research institutions in the field of science and technology, has extensively analyzed its transfer activities. They concluded that pursuing open approaches, such as free licensing of technical developments, produced a far-reaching impact for their transfer goals (Nilsen & Anelli 2016).

So, instead of focusing on technology transfer by patenting and licensing technological developments, institutions of this kind should publish knowledge in freely licensed publications, for example, via portals such as the *Journal of Open Hardware*.

4.2 Measures for the implementation of Open Science Hardware

Transfer offices are important factors for the successful establishment of open science hardware. In a sense, they already provide the infrastructure needed to make science more open. All that is needed is a restructuring of their work. Suggestions for this have been provided, for example, by the international GOSH network.[26] These recommendations include:

[26] https://openhardware.science/policy-briefs/

- Transfer offices should provide advice after an invention disclosure regarding open hardware and not support patenting in the first place.
- Instead of patent applications, technical developments should be extensively documented and published.[27] Support is needed for this, because documenting hardware requires special procedures, accuracy, and compliance with standards. One guideline for structuring good open documentation is DIN SPEC 3105-1. Transfer offices could support researchers and guide them through the documentation process.
- Transfer offices should also help build and maintain developer communities to make research projects with a focus on technology more sustainable. Building a developer community increases the likelihood that developments will continue to be worked on and used after the funding expires.
- Working with such open communities and producing open-source knowledge also requires dedicated skills. Therefore, competence building in the application and development of open-source tools is needed. This also includes teaching the basics of intellectual property law and collaborative work, for example, by conceptually designing courses with the re-usability of their results in mind.

5 CONCLUSION

Opening up universities (open science) and sharing scientific resources under a free license (open access) are important trends of our time (Morais et al., 2021). This increases trust in science, makes science more accessible, and improves scientific processes (Hyunjin et al., 2022). However, the focus on technical knowledge is lacking, especially in Germany. The patent as a publication form has not been the subject of open access strategies, although patents are an important part of the publication system. This leaves out knowledge about hardware and thus the development of scientific tools. But these are an important part of the science and innovation system. Publishing as open-source hardware could benefit these systems and reach a broader audience. This requires a cultural change on intellectual property and the reformation of transfer offices at universities. These should put fewer resources into patenting and licensing scientific inventions. Instead, they should support scientists in building developer communities and in creating and publishing open documentation.

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[27] The publication "Open-Source Photometric System for Enzymatic Nitrate Quantification" shows how this could be done: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0134989

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