



# On the Impact of Being Open

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**THERE'S MUCH DISCUSSION** about being open, with topics such as open source software, open innovation, open research, and open education. Will the whole world be open, and, if so, what was all closed in the past? Many people credit software with starting the open movement in 1983 with Richard Stallman and the GNU Project. Others credit Linus Torvalds with starting the movement when he put the first version of Linux online in 1991. Here, we analyze the similarities and differences between the open movements we've been part of and come up with expectations for software's future.

## Open Source Software

Software often starts as embedded software: it works only on a specific device and isn't separately charged. Next, it appears on the invoice as proprietary software but works only on the same company's hardware. IBM was the first company to enter this stage when it began selling software separately from its hardware in 1969. As software use expands, companies can't afford to develop all the required software themselves. This often leads to an industry or open standard, such as MS-DOS and Windows. The computer industry entered this stage when Compaq launched its PC in 1983, enabling startups such as Microsoft to sell their software on hardware from multiple vendors.

The next stage in software proliferation is open source.<sup>1</sup> Here, software is

developed only once and then shared with the world. Some open source software is created by volunteers. This alternative is also attractive for companies that face increasing software development costs and aren't in the software business. Open source has changed software development in many industries. Whereas an engineer once might have started a project with requirements or an overall design, the first step now might be to look for open source components that do more or less what the requirements prescribe. Of course, the open source code's licensing conditions must be fully understood.

Today, many open source products are among the market leaders in their field, both visible and invisible to users. Examples include Firefox, Android, Linux, and Apache. *IEEE Software's* Impact department has described four open source products: RealPlayer,<sup>2</sup> YAWL (Yet Another Workflow Language),<sup>3</sup> Bayesian networks,<sup>4</sup> and EYE.<sup>5</sup>

## Open Education

In 2001, MIT announced its intention to make all its learning materials freely available through the Internet. A 2002 UNESCO conference in Paris coined such digital learning materials Open Educational Resources (OER). This development was also one of the drivers of Creative Commons—an organization that defines and maintains an open license framework for all creative expressions. According to Creative Commons,

the number of works published worldwide under that license has grown from 50 million in 2006 to 882 million in 2014.<sup>6</sup> Exactly how many of them are learning materials is unknown, but the number exceeds many millions.

In 2011, Sebastian Thrun and Peter Norvig made their residential Stanford course on artificial intelligence available for participants outside Stanford. This attracted 160,000 participants, of which 23,000 finished the course, earning a certificate of completion. This marked the start of the massive open online course (MOOC) movement. A MOOC provides a complete learning experience: content delivered in chunks by short videos, quizzes with immediate automated feedback, and an online examination. With an adequate performance, the learner earns a certificate. There are an estimated 3,000 MOOCs worldwide, often offered by renowned universities (see [www.class-central.com](http://www.class-central.com)). Companies such as SAP (openSAP) and organizations such as the International Olympic Committee also offer MOOCs.

David Wiley characterized the “Open” in OER as freely available and permitting the user “5R” rights: the right to retain (make a local copy), reuse (as is), revise (alter the learning materials), remix (mix the learning materials with other components), and redistribute.<sup>7</sup> Many MOOCs provide only free availability and keep the learning materials closed. However, learning materials’ adaptability is important to make them fit the local educational context.

OER ultimately aims to provide higher-quality education. Its effect can be direct—for example, by making more digital learning materials accessible and creating more opportunities for new forms of pedagogy.

Other direct effects are OER’s improvement by peers and the opportunity to adapt OER to the specific educational context. An important indirect positive effect can be that teachers get inspired just by browsing OER materials. Another well-known effect is that the OER developers might pay more attention to quality because the materials are openly published and are reviewed by peers. Studies have verified this claim of higher quality.<sup>8–10</sup>

## Open Research

Unquestionably, open source as a development model has revolutionized software development. It has become a true cooperative movement producing software often of the highest quality and without which the Internet simply wouldn’t run in the same way. Perhaps lesser known but no less important has been its impact on scientific research.

Computation dominates the vast majority of scientific research. However, a fundamental principle of the scientific method, as promoted by the philosopher Karl Popper and others, is that the results must be independently repeatable. Results that aren’t repeatable are, to put it bluntly, useless. For example, consider the infamous 1989 Fleischmann–Pons experiment reporting cold fusion.

The advent of large-scale computation has greatly complicated this simple but profound principle. In essence, as Darrel Ince and his colleagues discussed, the description of an algorithm is simply insufficient.<sup>11</sup> Instead, researchers must be able to access the complete means to reproduce the computational results. This includes the source code the original researchers produced and the source code of the support software they used, such as Perl or R, as well as the

means to build it. (Even a different compiler switch can dramatically affect numerical accuracy in certain circumstances.)

With the advent of GNU/Linux and the many support systems written by enthusiastic volunteers worldwide, including statistics packages such as R, it’s now possible to reproduce computational results. This will likely pave the way for the next advances in scientific research, as we learn which of the many results produced are sufficiently reproducible as to be relied upon. However, until this practice becomes mainstream, many scientific studies’ computational results will likely be contaminated with unquantifiable errors. They simply aren’t scientific in the classic sense of independent reproducibility.

Another important trend is the rise of open access journals. It started as an attempt to break the stronghold of some scientific publishers that had scientists writing for them for free while charging increasing subscription fees. With the rise of the Internet, it became possible to collect, review, and distribute papers digitally at much lower cost. Research has indicated that publishing in open access journals leads to more citations, which is one measure of quality.<sup>12–14</sup>

## Will Being Open Take over the World?

We believe that, in the coming years, being open will take a larger place in the three fields we just discussed. The fact that we can now copy content for free and distribute it around the world for free allows the best content to travel to more consumers. Distribution has changed, and creation is changing as we speak. The worldwide distribution of software,

learning materials, and research products can be instantaneous and without cost.

However, this process still raises many economic and legal questions. The business models of being open and being free are unclear in many cases, and different license models don't allow the mixing and matching that some creators (such as software engineers and lecturers) would like. And, of course, software companies, educational institutions, and scientific publishers will do what they can to preserve their future. Some embrace the open future; others are trying to slow it down for as long as they can.

Sometimes valid reasons exist to keep things closed. For example, a company or institution needs to preserve and guarantee its product or architecture. A software company might have to guarantee that safety-critical software will work according to specifications and be willing to stand by its product in case of failure and any subsequent liability. A university will likely want to guarantee a consistent curriculum and offer a strong community of teachers and alumni. Some research journals have taken a century to achieve their fame and generate more citations than many open access journals combined.

A lesser-known effect is that being open will lead to more transparency, more competition at a larger scale, and less need for creation. We need great software, learning materials, and papers, but probably not that many because the winners will likely take it all. The main differences will probably be on the consumption side. Using software and software components shouldn't require much support. That is, users in many fields won't tolerate or even

use software that requires them to take a course or read a manual.

In education, using open learning materials might remain less universal. A considerable amount of materials in fields such as law or history are still specifically national or local. Also, it helps to have a teacher with whom you can discuss course content and who can quiz you to assess what you understand and explain it again with additional examples, if necessary. So, open learning materials might impede the local learning process and not be accepted by teachers if they can't adapt them. Also, most educational institutions don't have to make a profit, so the need for global efficiencies might be less.

**N**evertheless, some argue that being open will lead to better quality. Two mechanisms that help this process are reviews and the many users who help find problems early on. The evidence is being built continually, and although it's not quantifiable yet in all areas, being open has a strong argument in its favor if it's not only free but also better. 🌀

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