Technologist, Innovation explained

Opening up science

Sep 26, 2016

Science for all!

Scientists sharing their results on free online platforms? Citizens participating in major research projects? Engineers working in tandem with biologists? Welcome to the new way of doing science. Pushed by technological progress and the quest for solutions to increasingly complex problems, science is opening its borders. The "Open Science" movement is spreading around the world, touching every discipline, leaving behind the closed academic circles of yore. As a result, ideas circulate more easily and progress is quicker. But that's not all: research has also become accessible to those outside academia. Intense cooperation with industry and an enhanced dialogue with citizens have helped create science at eye level.

The birth of a movement

Since Antiquity, science has gone through cycles of openness and secrecy. The answers to four questions explain the current revolution.

How did the movement start?

With the digital revolution, a series of paradoxes brought science to a crisis. Far from becoming more evenly and easily distributed, knowledge has increasingly been held hostage by scientists, publishers and private companies. This crisis is not unprecedented. Since antiquity, science has gone through cycles of openness and secrecy.

When 17th-century scholars realised that keeping their results secret was slowing their progress, they began trading information for credit. "This first scientific revolution built a reputation economy in which researchers were rewarded not for the production of knowledge, but rather for disclosing it to the public," explains Bruno Strasser, a professor at the University of Geneva who focuses on the history of life sciences. "Together with the invention of the printing press, this led to a period of openness with the widespread adoption of scientific journals."

As publishing houses were gradually privatised, they started to abuse their dominant position as knowledge providers. In the last decade of the 20th century, the high fees they charged subscribers and their significant profits triggered resentment. Taxpayers who had already paid for the research would have to pay again to read the literature. Also, instead of using the opportunities for collaboration offered by Web 2.0, publishers still released scientific reports in a PDF format that was basically a bad digital substitute for paper. To address these flaws, several scientific communities decided to invent the future of knowledge dissemination. The open-science movement was born.

What does it take?

Sometimes referred to as Science 2.0, open science is a revolution in the making. People are building digital tools to help scientists share their research as soon as possible, throughout the entire research life cycle – from the initial hypothesis, during data collection and the experimenting phase, to dissemination of the results.

Open science is more than a publishing revolution. In his book Opening Science, Sascha Friesike, a professor at the University of Würzburg and researcher at the Alexander von Humboldt Institute for Internet and Society in Berlin, describes the five trends that compose the open-science movement. “As in any industry, user frustration is a powerful source of innovation,” he says. “Many of the tools developed to accelerate the pace of knowledge-sharing are launched by scientists.”

Some manage to stay in research while working on their solution. Lawrence Rajendran, a professor of neurosciences at the University of Zurich, recently founded ScienceMatters. With his start-up, he wants to revolutionise the way research results are evaluated and shared. “We try to fix as much as possible of what is broken in the current system,” he says. One example: instead of writing a story based on work carried out over several years, researchers can use ScienceMatters to quickly release a single observation. “Their work is judged not on the potential impact of the finding, but only on the quality of the science,” insists Rajendran. ScienceMatters is what is called an open-access platform: everyone can read it free of charge.
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Who benefits?

"Big science" experiments – large-scale projects that require multi-billion investments from governments – have always been open by design. CERN's Large Hadron Collider and the European Human Brain Project flagship program led by EPFL are two prominent examples of such international collaboration. But "small science" has much to learn from these examples. Sharing resources brings down costs and prevents duplication of data. Open-access publications can also have more impact, as measured by citations and media coverage.

"There is a wealth of information available already," says Gernot Abel, a science manager at biotechnology firm Novozymes in Denmark. "What we need is a more open conversation between two different cultures: academic curiosity and industrial innovation." People are central to this process, not data." Nicola Breugst, a professor of entrepreneurial behaviour at the Technical University of Munich agrees. "It is important that scientists make the information accessible, but also that they act upon the findings."

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People are central to this process, not data

What are the success stories?

Sharing not only the results but also the process of science is a key ingredient to making it faster and more collaborative. Instead of working alone, the 40 contributors of an online forum discussion needed only seven weeks to solve the first challenge of the "Polymath Project" launched in early 2009. With this spectacular case of "massively collaborative mathematics", Timothy Gowers, a professor at the University of Cambridge, demonstrated that many minds can work together to crack difficult mathematical problems. To insist on the collaborative dimension of the initiative, every paper that reported a solution was published under the pseudonym D.H.J. Polymath.

Global health is another discipline in which rapid access to results can make a difference. Recently, the threats of Ebola and Zika epidemics have led to faster and broader information sharing among research labs. More surprisingly, pharma-ceutical research, a field normally extensively protected by secrecy and intellectual property, has sometimes opened its vault. In 2010, JQ1, a molecule that showed great potential as a tool to study epigenetic mechanisms and treat various types of cancer was described by Jay Bradner and his team, then at the Harvard Medical School.

In a pioneering move, not only did they publish the chemical structure but they also agreed to send samples to anyone interested. The results are staggering: five years later, more than 500 labs worldwide have tested the JQ1 molecule and the original publication has been cited more than 800 times.

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Article by Luc Henry @heluc

Science in the age of Big Data

The digital revolution and the ability to process huge amounts of information have changed the way research is done. Here are three examples.

Just over 10 years ago, a tsunami of data began to advance. That wave has since magnified and inundated all areas of science. Of all fields, astronomy, physics and life sciences have long required the most intensive computing capacity. "But other sectors, such as social sciences, are rapidly catching up. Researchers now use smart technologies to observe behaviour rather than hand individuals questionnaires," says Professor Wil van der Aalst, head of the Data Science Centre at the Eindhoven University of Technology (TU/e). Scientists in most areas now use big data to push the limits of knowledge. "The theory-based approach has been replaced by a data-based one," van der Aalst adds.

Scientists use big data to compile and process enormous data sets. But costs can rise quickly. This has driven researchers to work together, even forming interdisciplinary alliances. Nowadays, biologists commonly team up with statisticians, and sociologists with mathematicians. Institutions share their infrastructure, giving rise to multidisciplinary research centres. This is also made possible thanks to political initiatives. For example, the European Commission has recently made open research data a default setting for all the projects linked to its science program Horizon 2020.

"Today laboratories don't have the capacity for all the expertise needed to conduct their research," says Professor Sune Lehmann of Technical University of Denmark (DTU). For more than two years, he studied the social interaction of his students by analysing gigabytes of data from smartphones.

1. Zerioing in on human behaviour

▶ The SensibleDTU project examines students' social interactions

Modern man communicates through several channels, including direct speech, telephone, e-mail, instant messaging and social media. This observation formed the basis of the SensibleDTU project launched by Sune Lehmann of DTU to gain insight into our social interactions. "To decode social systems, you have to understand how people communicate across all existing channels."

A thousand smartphones equipped with a software programme designed to collect information about social interactions were handed out to students. For two and a half years, until February 2016, they logged data provided by Bluetooth, text messages, conversations, e-mails and social media. Each device collected up to 100 megabytes of information per day. That's a mind-boggling amount of data to process.

"With 1,000 students, that totalled 100 gigabytes a day, for 1,000 days," says Lehmann. It took several years of technical preparation to figure out how to interpret all that data, because "smartphones don't measure social interactions directly." How did they go about it? For example, the strength of a Bluetooth signal varies depending on the distance between two phones, and that can be used to determine when the social interaction took place, Lehmann explains. GPS is valuable for studying the social context. "It doesn't mean the same thing if a meeting takes place in a café or in a bedroom."

Data analysis is already producing results that offer unprecedented resolution and density. Many fundamental aspects of social sciences are being factored in, such as confidentiality, academic success, gender differences, social dynamics and mobility. The most surprising application has been in epidemiology. "The networks of contacts between individuals may shed some light on the way infectious diseases are transmitted." Lehmann (@suneman) hopes to use Facebook's social network to stop viruses by advising groups of people identified as being at risk to be vaccinated.

2. Making driving safer

▶ Vehicles chock full of electronics collect valuable information that can be used in driverless cars

Cooperative driving is a system that lets vehicles communicate with each other and their environment to improve road traffic and the information used by driverless cars. Researchers from TU/e and its Smart Mobility Strategic Area are working to develop cooperative driving systems that pack electronics into everything from passenger cars with drivers to robot football players.

Data are collected from a wide range of systems, including GPS, ABS, gyroscopes, wheel rotation sensors and Wi-Fi. A whopping 100 terabytes of data — the storage space on 400 iPads — are generated every hour, says Carlo van de Weijer, director of the Smart Mobility programme. Cooperative driving offers numerous advantages. Cars optimise space and distances, consume less fuel and share any event useful to other vehicles to make roads safer and improve traffic flow. But, says van de Weijer, the technology still needs development. "Safety is close to 100 per cent, but the tiny percentage left would cause several accidents a day if all vehicles were autonomous."

3. Exploring a milennium

▶ The Venice Time Machine will need 10 years to scan 1,000 years of history

The impact of Big data on society

Winning elections In his successful 2012 re-election campaign, Barack Obama used digital information to target messages to specific voter groups.

Decoding the human genome At the beginning of the 2000s it took up to 10 years to decode a human genome, which is composed of 3 billion nucleotides. Thanks to Big Data, it now takes only one day.

Avoiding crime In Modesto, California, the police use Big Data to track criminals. Using information on every crime committed in the city since 2004, they have reduced the number of burglaries by 27%.

The basic algorithms that made massive data collection and processing possible date to 2004. These new tools, however, cannot use much of the information pre-dating that period. Yet "the past urgently needs to become as easy to access as the present," says Frédéric Kaplan, who leads the Venice Time Machine project at the École Polytechnique Fédérale de Lausanne (EPFL). He aims to discover the floating city's secrets by scanning its archives and cultural works.

A daunting task, to say the least. It will take 10 years to scan the 1,000 years of history carefully guarded in 327 rooms full of birth, marriage and death certificates, wills, business records, tax returns and the addresses of Venetian residents. But that's not all. The archives also contain diplomatic documents. "These logs offer such a wealth of information that they alone could be used to retrace a good chunk of European history," Kaplan says. The biggest challenge is not so much the volume of data as finding a way to scan the billions of pages without damaging them. "We've developed a semi-automatic scanner that can process 1,000 sheets per hour." The team has even considered using medical imaging techniques to scan books without opening them. "It works – but these processes are still under development."

Another challenge is recognising characters in manuscripts. "We've teamed up with no fewer than 15 universities to come up with solutions." EPFL has focused on writing algorithms that can transform the scanned images into words and sentences. The end goal is to design a Google-like search tool to use the database. Scientists have linked key words to documents and organised information into huge graphs of interconnected data.

Frédéric Kaplan, EPFL, introducing the Venice Time Machine. EuroTech Open Science High Level Event, held at the Belgian Institute of Natural Sciences in Brussels, Photo: Eric Berghen, September 21, 2016.

The system used by Venetian archivists is helping researchers do that, as it was the precursor to modern indexing systems. EPFL has also been working with the Fondazione Giorgio Cini since March 2016 to scan and digitise paintings. The foundation's archives include works by Piero della Francesca, Fra Angelico and Sandro Botticelli.

Article by Yann Bernardinelli @YB_SciRedac

The inevitability of free papers

Scientists are making headway in challenging the traditional publishing model for research papers. The big winners may include ordinary citizens.

"The time for talking about open access is now past. With these agreements, we are going to achieve it in practice." So said Dutch Research Minister Sander Dekker in Brussels at the end of May, after he and fellow EU ministers unanimously agreed that all scientific papers reporting publicly funded research within Europe should be freely available on the Internet from 2020 onwards. In other words, forget subscriptions to scholarly journals. Anyone – scientist, medic, student or ordinary citizen – will be able to download research findings at the touch of a button and free of charge.

Around for more than a decade, this vision of "open-access" publishing is supported by numerous academics, policymakers and librarians. But in the last few years the idea has been gaining ground. In fact, it may have acquired unstoppable momentum, thanks to both the opportunities offered by the Internet and anger at the rising profits of traditional journal publishers. Scientists argue that the work they carry out and peer-review should not be hidden behind publishers' pay walls.

Ralf Schimmer, a sociologist at the Max Planck Digital Library in Munich, argues that it is unrealistic to think that all papers could be published using open access as soon as 2020. But he does believe that by then scientific publishing will have reached a "point of no return" where complete open access becomes inevitable.

From brain to particles

One prominent open-access project is Frontiers, a purely online set of journals set up in 2007 by Henry and Kamila Markram, both neuroscientists at the École Polytechnique Fédérale de Lausanne. Kamila Markram says that they embarked on the venture after getting fed up when a significant number of what turned out to be highly cited papers were rejected by top-tier journals after peer review. This "rejection cascade", she argues, wastes scientists' time and harms the economy.

With Frontiers, peer review is used only to assess the technical quality of a paper. Judgement of a paper's importance is instead left until after publication; it is measured through quantitative "article-level metrics", such as how many times a paper is downloaded, cited or even mentioned in a tweet. Markram maintains that this overcomes the problem of a reviewer's subjective bias, which might prevent perfectly valid, perhaps even groundbreaking, research from being published. "We are moving very far away from the model where one almighty editor decides these things," she says. Meanwhile, a project known as SCOAP3 – the Sponsoring Consortium for Open Access Publishing in Particle Physics – is showing how to apply the open-access model to an entire field. It requires university libraries to put their subscription budgets into a central pot that researchers draw on to publish their papers and make them freely available. Hosted by the CERN laboratory in Geneva and backed by some 3,000 libraries, funding agencies and research centres, the project was launched in 2014 and was recently extended until the end of 2019. It involves eight journals, although the largest in the field – Physical Review D, published by the American Physical Society – is absent. Other fields have yet to follow suit. Currently only about 13 per cent of all papers published in scholarly journals are freely accessible. Schimmer says that part of the problem is a perception by some librarians that open-access publishing will cost them more. However, an analysis he carried out with two colleagues at the Max Planck Digital Library last year showed that this is unlikely. The €8 billion a year spent in journal subscriptions worldwide divided by the roughly 2 million papers produced yields an average price per paper of about €4,000. In contrast, they found, open-access publication typically costs about half as much.

Making an impact

Schimmer says he is not looking to drive traditional publishers out of business. For example, he notes that physicists continue to subscribe to peer-reviewed journals even though they upload their papers to the freely accessible arXiv server (prior to review). However, argues Schimmer, what must change is publishers' business model. He believes that, rather than relying on what he sees as opaquely priced reader subscriptions, they should charge authors or their institutions for each paper published.

Unsurprisingly perhaps, traditional journal publishers see things differently. The Nature Publishing Group, for example, produces a number of open-access journals and also lets authors archive their papers online starting six months after publication. But, as the company outlined in 2011, it does not believe "one size fits all". It argues that while open-access publication is most suited to cheaper, lower-circulation journals, subscriptions are best for the leading titles. That way, it says, the higher cost per paper – due to lower acceptance rates – can be spread among the greater number of readers.

Indeed, some researchers worry that requiring authors to foot the bill risks a drop in standards. They argue that open-access publishers can reject fewer papers in order to make more money. In fact, Frontiers has been criticized for making it very difficult for reviewers to reject research, no matter its quality. But Markram defends Frontiers' peer-review process, saying that as they have published more papers their journals' impact factors – which record the average number of citations per paper – have actually gone up.

Schimmer believes that even the most prestigious journals, such as Nature or Science, could be made open access – both because the high costs per paper would be diluted by the lower costs of other, more numerous journals, and because many scientists would still be prepared to fork out for the prestige associated with publication in such journals. But time is running out. "If publishers refuse to change then change will be forced on them," says Schimmer.

“People who are in their twenties will not tolerate such a ridiculous and antiquated system. They will simply pull the plug.”

Article by Edwin Cartlidge @EdwinC_01

Medicine: Ethical questions

Sharing medical data leads to more targeted treatments, but also bears the risk of abuse. Adam Molyneaux of Sophia Genetics discusses the complexities.

Lausanne-based Sophia Genetics was co-founded in 2011 by molecular biologist and entrepreneur Jurgi Camblong (@JurgiCamblong) to turn the raw data produced by gene sequencing machines into useful diagnostic information that allows patients to get quicker, more targeted treatment. The company now serves some 160 hospitals in 25 countries, which in turn provide the mass of raw data that allows Sophia Genetics’ artificial intelligence software to better spot the telltale signs of hereditary and other illnesses. The firm’s Chief Information Officer, Adam Molyneaux, describes the technical and ethical challenges.

TECHNOLOGIST **How is your technology used for diagnosis?**

ADAM MOLYNEAUX A doctor sends patients’ blood samples to a local hospital lab, which extracts DNA and puts it through a sequencing machine. The resulting genetic sequences are sent to us over a secure data link; we then stitch the sequences together and compare the genomes that emerge with a reference genome from a healthy person. Any differences between the two might indicate disease-causing mutations.

TECHNOLOGIST **Why can’t hospitals do the analyses themselves?**

ADAM MOLYNEAUX Each step in the sequencing process adds errors, which means that if you don’t clean up samples what appear to be mutations could in fact just be artefacts. We use neural networks to analyse gene sequences to sort the wheat from the chaff. This saves clinicians time, but it is always they who have the final say on the significance of a particular mutation.

TECHNOLOGIST **Why is it good to connect lots of hospitals?**

ADAM MOLYNEAUX The more data we feed our neural network, the more accurate its predictions will be. Every time a clinician decides whether a feature we flag is in fact pathogenic we feed that decision back into the network, so it learns. This means that each decision benefits all of our clients even though they don’t see the underlying data.

TECHNOLOGIST **How do you keep those data private?**

ADAM MOLYNEAUX We do whatever hospitals tell us to do with the data – whether to save them or destroy them, for example. We can’t publish them and can’t sell them. What’s more, hospitals keep the data anonymous by replacing each name with a number.

TECHNOLOGIST **Can you explain the problem of incidental findings?**

ADAM MOLYNEAUX A patient being tested for colon cancer may, for example, turn out to be susceptible to Alzheimer's disease. That raises questions: should the clinician see those extra data, and, if so, should they report the results to the patient? It's also possible for genetic data to identify a child's real biological parents.

TECHNOLOGIST **Are these problems technological or ethical?**

ADAM MOLYNEAUX We're currently working with a professor of cryptography to mask certain sections of the genome to prevent incidental findings from "leaking out". But technological fixes can only get you so far. The case of identifying parents, for example, has to be handled ethically. In Europe, legislation protects the confidentiality of patients' data.

Article by Edwin Cartlidge @EdwinC_01

Power to the people

Citizen science relies on the public's curiosity and enthusiasm – not to mention computing capacity – to supplement the work of scientists. The results are not just symbolic, but real.

Each day, tens of thousands of neophytes set to work transcribing museum archives or observing the animals of different national parks on the citizen science platform Zooniverse. They're part of a new wave of non-professionals who, curious and eager to help, are becoming involved in areas beyond those in which lay people usually contribute, like astronomy and ornithology. "Amateurs have always participated in scientific research," says Sascha Dickel, a researcher in the sociology of science at the Technical University of Munich. "Their exclusion is a relatively new phenomenon which started in the late 19th century, when science became professionalised."

Stay-at-home particle physicists

Though CERN's research findings routinely make headlines, most people know little about how the Geneva-based nuclear research organisation functions. But since 2004 anyone can participate from the comfort of home, just by making his or her computer's power available to CERN (see below "Solving the universe's mysteries" Solving the universe's mysteries).

"People really want to contribute," says Laurence Field, an IT engineer at CERN. "The general public remains an underutilised resource." But there's a real need for such help: CERN lacks the infrastructure to analyse all the data it produces. Volunteers are actually the second largest producer of simulations for one of its experiments. Even though projects like the one at CERN are open to anyone with a computer and Internet access, studies show that the participants are mainly tech-savvy computer geeks.

Citizen science also attracts people for tasks that cannot be automated, often in the form of games. Galaxy Zoo has been a huge success, with about 50 publications under its belt. In 2007 Chris Lintott's astronomy research team at the University of Oxford was struggling to classify more than one million images of galaxies. "The algorithms couldn't differentiate between elliptical and spiral galaxies, whereas humans can easily recognise those patterns," explains Laura Trouille, who oversees citizen science at Chicago's Adler Planetarium, a partner in this trans-Atlantic collaboration.

Lacking the resources to perform these classifications by hand, the team allows people to analyse the images on the Internet. So far it's a huge success: within 24 hours of launching the project, the team was already receiving nearly 50,000 classifications per hour. After a year, that number had reached more than 50 million.

Galaxy Zoo's success gave rise to the Zooniverse platform, which includes some 40 citizen-science projects in fields ranging from astronomy to social sciences (see "Glimpsing into the artist's mind", opposite).

"The public's help is making a real difference," says Daniel Lombraña, co-founder of Crowdcrafting, a platform on which people can create citizen-science projects. "Working with Cancer Research UK, we've shown that users can recognise cancer cells almost as well as experts can." After a brief tutorial, 1,000 volunteers learned to identify cancer cells in photos of tissue samples with 90 per cent accuracy.

Human Detectors

FabLabs and science shops are other examples of successful citizen participation. The goal is to get the public even more involved in research. FabLabs are collaborative, creative spaces in which people can access an array of tools, from 3D printers to laser cutters. Teja Philipp made use of several FabLabs in Munich and Berlin when designing the prototype for his "Mr Beam" portable laser cutter. The project's recent Kickstarter campaign was one of Germany's most successful to date, raising more than €900,000.

Science shops, on the other hand, are more of a cross between university and society. They receive questions and requests from non-government groups on issues such as local pollution and traffic management, and conduct research with university partners to come up with solutions.

Projects like Zooniverse attract people of all ages, half of whom do not hold a university degree. But there is no consensus yet on whether these initiatives are actually getting broader groups of people involved in science.

"Most projects ask people to perform tasks that require little expertise, limiting their role to that of a human detector"

"The alternatives, however, attract narrower groups. So we're faced with the choice of either getting as many people as possible involved or giving more responsibility to participants,"says Dickel.

Article by Carine Neier

You, too, can be a research scientist

With these four citizen projects, anyone can help advance knowledge without leaving home.

▶ **“Solving the universe’s mysteries”**

Website: lhcathome.web.cern.ch

By whom: CERN Since when: 2004

How to participate: Volunteer your computer’s power to help physicists analyse data from CERN’s Large Hadron Collider. Install the appropriate software to start running simulations when connected to the Internet. The software may be configured to run at the lowest priority or not at all while your computer is in use.

Simulations completed: 3 trillion

▶ **Connecting brainy dots**

Website: eyewire.org

By whom: Massachusetts Institute of Technology and Max Planck Institute of Medical Research

Since when: 2012

How to participate: Play a game to help researchers map and understand the trillions of connections between neurons in our brains. After registering on the website, players solve 3D puzzles to earn points while building the model for neurons in a microscopic retina sample.

Players: over 200,000

▶ **Glimpsing into the artist’s mind**

Website: anno.tate.org.uk

By whom: Tate Gallery and Zooniverse Since when: 2015

How to participate: Transcribe handwritten texts from artists’ sketchbooks and letters to help the Tate digitise its archives. Tasks are completed on the project’s website, with the option of transcribing one or more lines of text from the personal documents of Francis Bacon and 30 other painters, photographers and sculptors.

Documents transcribed: 17,000

▶ **Evolving at a snail’s pace**

Website: evolutionmegalab.org

By whom: The Open University and other European contributors Since when: 2009

How to participate: Hunt down common snails in your garden and record their colour and pattern. Mapping banded snails' characteristics throughout Europe will help researchers confirm whether their evolution is linked to climate change – possibly because darker shells warm up faster in sunlight. For all ages, available in 14 languages.

Records submitted: over 10,000

Labs without borders

Designers working with biologists and engineers: not so long ago such collaboration would have been unusual. Now it is at the heart of European Science.

Yuan Lu, Associate Professor, Department of Industrial Design at Tu/e, showing one of the devices of the REACH project, during the EuroTech Open Science High Level Event, held at the Belgian Institute of Natural Sciences in Brussels, Photo: Eric Berghen, September 21, 2016.

If scientists hope to receive funding from major programs like the EU's Horizon 2020, they had better heed one of the European organisation's principal requirements: collaboration across fields. "At the beginning of the 2000s, we tried to integrate two or three disciplines into our projects," recalls Thomas Linner, a senior researcher at the Chair of Building Realisation and Robotics at the Technical University of Munich. "Now that number can reach seven."

Linner is currently pulling together the "Reach" project with colleagues at five other universities – including the Technical Universities of Denmark and Eindhoven as well as the École Polytechnique Fédérale de Lausanne. Using body sensors and real-time data analytics, Reach is developing technologies to prevent health problems for elderly people. With the involvement of industry and healthcare partners as well, the researchers need to harmonise 17 different areas of knowledge. "A particular challenge is that data engineers are learning to work with professionals from the healthcare sector," he says. Linner expects a yearlong learning phase until collaboration processes run smoothly within the project, which was launched this year.

Antidisciplinary space

The Massachusetts Institute of Technology's Media Lab has focused on collaborative projects since 1985. Its Center for Extreme Bionics brings together mechanical engineers, synthetic biologists and neuroscientists to tackle impaired mobility due to trauma or disease. In 2014, Media Lab director Joi Ito wrote: "As we engage in tackling harder and harder problems that require many fields and perspectives, the separation of disciplines appears to be causing more and more damage." Last year, the laboratory launched the Journal of Design and Science, a publication in which science, art, design and engineering meet in a common "antidisciplinary space". According to Linner, research in the U.S. is not only a model for interdisciplinary collaboration, but also for more market-oriented work. "In Europe, there is a push to collaborate with industrial partners right from the start," he says. "Science is becoming more and more application-oriented. With Reach we want to create devices that provide our industry partners with a market-leading position." Or, as MIT's Ito puts it:

"Deploy or die"

Article by Robert Gloy [@robertgloy]

MOOCS: this revolution will wait

They're more and more exclusive And they're often full of already highly qualified students. Are Massive Open Online Courses failing to democratise education?

The figures are impressive. The online education platform Class Central reports that, between 2011 and 2015, 35 million people enrolled in at least one MOOC among those offered by more than 500 universities worldwide. Does that justify the name of the Massive Open Online Courses, which were meant to make higher education available to all?

Some feel that MOOCs have failed to deliver on their promise. "Several studies show that most of the people who take these courses already have roughly the equivalent of a master's degree," says Marc Trestini, professor and researcher at the University of Strasbourg and an expert in digital learning environments.

This has also been the experience at the École Polytechnique Fédérale de Lausanne (EPFL), which spearheaded the MOOC movement in Europe by first offering courses back in 2012. Of those enrolled in the 50 or so online courses now available, 72 per cent already hold a university degree. "The courses provided by universities like ours are difficult for anyone who doesn't meet the prerequisites," says Pierre Dillenbourg, head of the MOOC project at EPFL.

As Professor Trestini suggests, the prerequisites do not include theoretical knowledge alone. "To take a MOOC, you first have to know what it's about and have the time required to complete the course. You also have to have some understanding of different learning strategies and be able to apply them." So education remains a privilege, and online courses cannot completely overcome that. Was it idealistic to think that we could "democratise" education? Not according to Mr. Dillenbourg. "Democratisation means open access, not guaranteed success."

Finding the right model

The leading providers of MOOCs, such as Coursera and edX, are trying to maintain open access to the online courses. The modules are still free but students are starting to have to pay to obtain their certificate. This concept was embraced at EPFL. "We offer courses that provide useful skills for the job market. Students are willing to pay for a certificate. But we have to focus on how much the certificates generate to continue offering the rest for free," Dillenbourg says. The Open University and the University of Leeds in the United Kingdom have recently introduced programmes that allow students to take MOOCs as part of their degree. Schools partnered with the German platform Iversity also have the opportunity to award course credits. But once again, students have to fish out their wallets to obtain official certification.

While trying to work out the right business model, online course providers are also struggling to define the educational model. MOOCs generally used to fall into one of two categories: xMOOCs, with a professor teaching students a subject, and cMOOCs, which take a more connectivist approach to learning. Today we hear a lot about SPOCs, or Small Private Online Courses, designed for a limited group of students with a more defined course structure.

Mr. Trestini thinks that online courses will move towards more teacher-directed approaches "because online users need structure". But the educator fears that could erode their original mass appeal. "If we continue limiting MOOCs, we could eventually strip away the whole point. SPOCs are MOOCs for smaller numbers of students. They go back to the traditional forms of distance learning. But MOOCs were promising something else."

For EPFL, diversification is the key. In addition to very academic-style MOOCs or MOOCs designed specifically for African universities, the Swiss institution has recently introduced a professional development programme. MOOCs "haven't changed the world," Pierre Dillenbourg admits, but he reiterates the positive aspects. "Students from 186 countries have been able to enroll in EPFL courses. MOOCs also give professors the opportunity to explore other educational approaches and find useful examples for their courses."

Article by Marielle Savoy @mavoyelle