Arduino is an open-source electronics platform based on easy-to-use hardware and software. It was designed for anyone willing to do interactive projects. It has a large section dedicated to education. One can find everything needed to integrate technology into design and detailed guides to build many devices, such as a bicycle speedometer, an ambient temperature meter or remote control to operate a toy tractor.

Ardunio and the art of making difficult things easy

By incorporating design into technology, we enter a new world where anything seems possible.

by Ana Moreno

INTERVIEW WITH DAVID CUARTIELLES

David Cuartielles has a PhD in Interaction Design and a degree in Telecommunications Engineering and is one of Arduino's co-founders. He founded the IOIO lab at Malmö University. He teaches interactive technologies at bachelor, master and doctoral levels. His research includes analysis of platform creation, prototyping and testing tools for education and the study of visual programming languages. He also collaborates with several universities as an educator in interactive art, creative coding, interaction design and embedded technology.

As co-founder of Arduino and professor of design at Malmö University, you have managed to ease the difficulty by integrating technology into design. Could you explain what Arduino is and how it relates to design?

Arduino is a platform of free software, hardware, and documentation created to bring digital technology to students of industrial design, interactiv and art.

In the 2000s, the need of bringing technology closer to this type of training arose. Introducing automation and digital control in the production and creation processes was beginning to be glimpsed. As a result, a strong interest was generated in different schools, such as the School of Art and Communication in Malmö: studying how digital technology, previously confined to engineering, could be transversally integrated into other areas. This involved reviewing many things: the pedagogy, the used tools, and how effectively work with a transversal curriculum.

The relationship with design is twofold. On the one hand, design was Arduino's client from the start. Moreover, on the other hand, when creating Arduino, design was crucial: we placed ourselves in the situation of studying how to teach in the field of design, introducing different types of tools and how design can help to create new digital or physical products with a digital body.

This required an intense design process: studying the end-user, finding a way to give the user a voice and involve them in the creation process. As a result, the Arduino platform emerged, where everything is designed to meet its users' different types of needs.

An example of the importance of design can be seen in the *Arduino 1* board, which was a great success. It has been working for more than ten years in many people's computers and survives very well through continuous technological progress. This board includes several features that make it very good for education at any age. First, it is very robust technologically speaking: it can be dropped, or wet, or you may have an accident, but it can easily be dried, and it works again; you can cut a piece out of it, but -if you know how to cut it- it still works. Second, it works with any type of computer or operating system. Third, it is electrically well protected: if there is a small short circuit, the board does not burn out. Finally, the components

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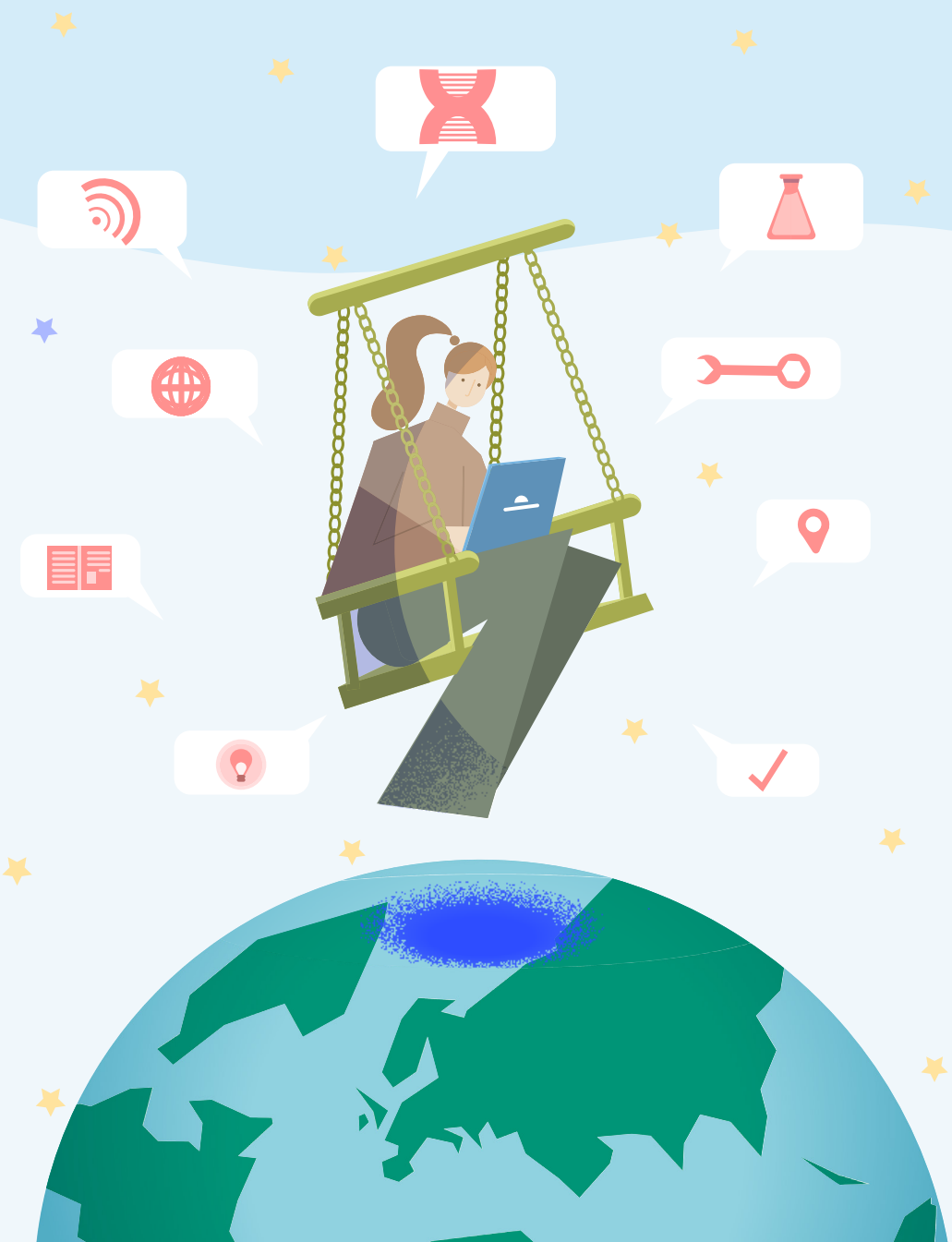
are pretty long-lived, and they will last for years and years, while a school will just for few years.

The key to success was that we thought about what was necessary for the teachers and students who would use this system from the very beginning. As a result, it is the first time that this whole design process has been applied to an educational tool.

There is a moment when Arduino enters the world of education and, in some aspects, revolutionises the way technology is taught. How did the idea come about? At what level is it widespread in the world of education? What does Arduino contribute to the training of new generations of children and young people?

I teach at the School of Art and Communication. My students generally have no technical background, so I started this project because of the needed tool to introduce technology in the university classes.

We soon started to see some interest in this tool from other academic and non-academic communities. *Arduino Education* is a project created within Arduino, and that has grown a lot in the last few years. It all started in 2005. In 2006 I began to investigate what kind of communities I was most attracted to because I started this project out of passion, and I wanted to continue working in the same way. I realised that VET schools had a problem with their equipment. It was often outdated, or they were very dependent on specific suppliers. Having an open tool allowed them to have the possibility to do it themselves if a supplier failed or to have several suppliers to be able to work in the same field, which is what happens now. Arduino boards are open, and you can find official and unofficial ones.



Thanks to the intermediation of *Medialab Prado* in Madrid, I started working with a teacher on creating the curriculum for what would be an academic course in which projects based on digital technology would be done. The objectives were mainly learning how to program, the basic history of digital components, and a small project. The course included a traditional theoretical-practical part and another innovation and creation oriented.

We piloted the course in a public high school. The teacher was working with a group of troubled, often segregated pupils, and in that case, it had a spectacular result. So I started looking at how this could be introduced in other parts of the educational system and started investigating how to collaborate with different actors to create their educational content and not do it from Arduino.

I needed to see how a more or less generic tool could be adapted to different contexts. So we did a course for teachers on technology and how they could use it in their classes. It was very successful and caught the attention of AEFIC (European Association for Education and

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Research in Science). And they invited me first to give a course in a centre in Buenos Aires and then in 2008 to 25 science teachers in which we looked at how Arduino could be used to generate science experiments. In the course, after an introduction to the technology, each teacher had to propose an experiment. I continued to do this on numerous occasions until 2012, when the opportunity arose to do a scalable experiment with schools in the community of Castilla-La Mancha. We started creating the content in January and February 2013, and I simultaneously started the project with 400-odd students.

The experiment was challenging. We came in with a concept of introducing technology when everyone talked about teaching robotics in the classroom. Many teachers were doing it independently with no set format, no systematisation, no way to evaluate. So we offered a platform that we had co-created with the teachers and a way to measure together how they could make progress with the technology. Also, using technology innovatively and creatively and was very impressive: it worked very well.

We started repeating the initiative. It was financed by Fundación Telefónica the first year and by Fundación la Caixa the following ones. Thanks to this, 2,000 schools or so were reached throughout Spain over four years. In addition, science fair-type events were held in which some 4,000 pupils presented their projects. Thus, we jumped from 400 to 4000 students, an incredible leap.

There were many exciting initiatives: a professor at Sapienza University in Rome has just published a book with Springer called *Science Experiments with Arduino and Mobile Phones*.

We have come up with a robust tool that is easy to use in conjunction with devices that everyone has, such as a mobile phone. We think it can become the pen and paper of the future for science and technology experiments. The question is how to combine them. I believe you need to empower teachers to understand how the tools work. If you get that tool to be just that pen and paper, the day a tool wears out or goes out of use or something better comes along; they can change. This is the challenge, and I think Arduino has achieved it.

The Pandemic has been a turning point in the way we look at many things. One of these is the need to develop the creative and innovative capacity to find practical solutions to new situations urgently. How could the Arduino help in this regard?

The issue, in this case, is twofold. On the one hand, Arduino has been used as a tool during the Pandemic, not only in education but also in many field. Moreover, on the other hand it is, what Arduino has done as a project and as a company during the Pandemic to facilitate education, given the imposed conditions of social distance and working individually.

Arduino education has always been based on finding the most convenient way to bring digital education to schools. This involves reusability and low price, among other factors. When designing educational *kits*, we thought about a class having seven boards for about 30 students so that there would be one for the teacher and one for each group of students, for example, 5.

When the Pandemic hit, this could no longer be the case, and we had to rethink how to generate the entire education system on an individual basis. We did a high-speed migration in a matter of 3 months so that all the most popular primary educational content at that time could be used individually. In addition, the costs were revised.

To give a curious fact, at Arduino, we saw from a business point of view that *Arduino Education* was not going to make money by 2020, yet we invested in helping. We had many people dedicated to the company, and we didn't want to do an ERTE. The truth is that the investment was worth it in all aspects. On the one hand, many people were interested in continuing to work, and the only thing they needed were tools that would allow them to separate the students from each other. And it has been highly successful. Now we know perfectly well that if an educational region wants to equip many schools, it is easier to provide with lab kits than with personal kits: it is better in the long run.

Furthermore, on the other hand, Arduino is a European company. We have offices in three countries: Sweden, where I am; Switzerland, where we have the intellectual property office; and Italy, where we have the factories. We also have people working in many countries such as Germany, Denmark, Spain and the United States.

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When the confinement started in Italy, the production stopped except for the Arduino, because many people used *Arduinos* to make alternative medical equipment. We worked very hard to get the Italian government to produce an exemption document to continue working. We had to invest in protective equipment for all our team and for the companies we work with.

There is much talk about introducing programming and robotics as curricular content, and there are countries that have already done so. What do you think? At what level do you think it could be helpful for the general population in the not too distant future?

Some countries already have a national or regional technology introduction plan. For example, the United States or the United Kingdom have regulated curricula.

However, there is a problem at the transnational level. For example, when comparing the US and the UK curricula, they are not strictly similar. There is agreement on how much mathematics a person has to know when they get to university, but not how much programming. We cannot answer this question because it is still unclear about the technological skills required to be a good citizen. We are all clear about basic mathematical skills, social-ethical skills, linguistic skills, and so. However, technological skills are not, and even less so between countries. At the moment, this is used as a tool to have a competitive advantage over another country; that is a fact.

This raises a rather crucial ethical question. When education becomes a political tool, we have a problem and improving the system becomes complicated. Everyone wants to promise more jobs and thinks that by educating people in technology, they will have more jobs later. But this is only true for those who come first; those who come second do not have it anymore. It is like the paradox in Spain in the 80s: if one learnt English, it was straightforward to find a job, but in 2000 if one is not good at English, it is nearly impossible to find one. This is the problem that we will have, at the beginning when you know programming and technology, in general, it is easier to find a job, enter more complex careers, etc. Later on, the problem will be that if you can't speak English, you will not get a job, which is the challenge we have to start to face. As soon as we have measured the minimum requirements that everyone should know, anyone who does not know them will not pass the filter. That is why the real ethical challenge is to achieve quality education for all.

There has long been a great concern to increase scientific and technological vocations. There is currently a myriad of STEM initiatives to encourage them. Do you have any ideas about what else could be done, and can you think of ways to make more girls and young women see this path as attractive?

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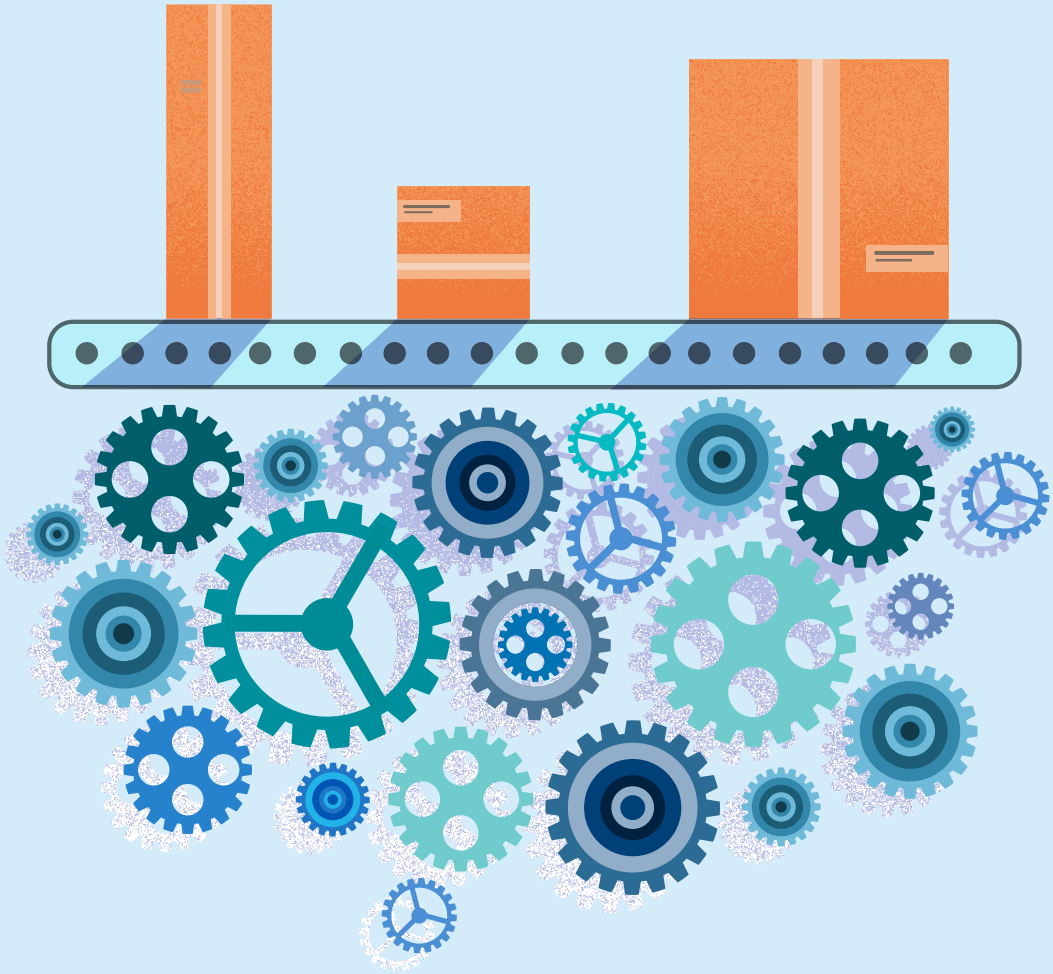
Access to technological studies is essential not only for women but also for all discriminated groups in general. I have, for example, taught a design class to a student who constantly needed an assistant and forced us to rethink pedagogy. My colleague Tom, another of the creators of Arduino, and I reviewed the way our development system works to be able to work with blind students.

Another important aspect is how to attract women in general to what would be the new technologies: that is a discussion in which I am not equipped to speak much, but I can say that in my faculty, the gender ratio varies greatly, there are years when we have 50% of girls, others when we have only 20% and years when we have 70%. We are a school in which there is a strong emphasis on technology: you learn to programme, you learn electronics, you learn how to work in a workshop, you design interactive objects, etc. We have done studies and tried to analyse the marketing we do in the city centres, and so on; the only reason we have found is a mere statistical question, with no correlation whatsoever. We did not expect that. I know that there have been experiments with changing the name of the educational programme in Spain and putting the word design so that more girls would enter, for example.

As for the idea of making the country more competitive or not competitive, I believe that the issue is not so much to make the country competitive but to help people to grow and develop as people in the future and to have a good life in harmony with the environment.

For that, we first of all need to educate in values. I believe that educational centres at a basic level try to do this, but it is our society that does not cover it. If a kid sees on television that you earn much more money by fooling around in a programme than by studying hard



It is still unclear about the technological skills required to be a good citizen.

for a long time because studying engineering is not easy and it takes time, and we cannot sugarcoat it; if he has to balance the two, what will he be left with? Without seeing that there is a relationship between today's effort and long-term values, it is challenging to get people to make an effort to study, not just technology, but to study in general. This is not only happening in Spain but also in Sweden. So we have to rethink at a social level what kind of values we are transmitting and why the culture of effort is being erased.

When we generate technology for people to learn, we are also softening the interface; we make it easier for people to be attracted and easier to participate in that process, learn, and use it.

This is one thing I always ask myself facing the debate about how children should learn to programme, in blocks or code? Of course, I always lean towards learning to do it in blocks, which is more accessible. But so far, very few studies show a strong connection between the understanding of systems and mathematics thanks to blocking programming as opposed to that acquired by programming in code. And code to this day is still how things work. So if you teach them to program in blocks, they will have to relearn how to program when they jump to code.

Maybe we should not soften that part of the process so much, but we should look for a way, a better pedagogy, to explain those complicated things so that people have better access and a better entry to the technology.

We live in a society in which we are trying to make the minimum effort, we create technologies to do so; however, this is where the catch that bites the tail comes in, programming technology sometimes cannot be done with the minimum effort, sometimes it requires taking a firm step of abstraction.

Many people think that learning technology is done with one class

a week for a whole year, that this is programming, but this is not true. You have to program in 1st, 2nd, 3rd etc.; you have to program even at university. You do not just learn it in one course, and that is it; it is the same as learning a language: you learn it over many years, it is complex, and it takes years to understand how it works. When you learn mathematics, you do not get a brushstroke; you learn arithmetic one year, then algebra, second-degree equations afterwards, and advanced calculus far ahead. This approach has not yet reached technology.

I think that improving teaching would also change things. Teaching is your primary job, but you have to research how you have to teach from the field you lead in to find the most efficient way to transmit that knowledge and make it more functional and, besides, nothing is static: everything has to be constantly changing because people change, society changes, tools change. This is one part of the debate. The other part of the debate is about how you know that everybody learns.

I am a telecommunications engineer; I have always thought of this from the point of view of AM radio. The traditional AM radio can be made with a receiver, a potato, a capacitor and a loudspeaker. This is the radio we can never give up because, with minimal components, we can make a communication system that can reach the whole of society. However, it is much more efficient to use FM technology, let alone digital. However, there is one fundamental thing that we cannot take away.

The same approach would have to be seen at the level of digital education; if society functions digitally, what are the potato and the condenser of digital technology that everybody has to learn that we cannot take away? Because you have to have that part, otherwise it will be very tough for people to really understand how the world they live in works: it is going to be all black magic.

According to a study by *Microsoft Research*, even people who cannot read look at their mobile phones to communicate. The important thing is that if learning to read is a right, learning how everything around you works should also be a right. So let us think about it, about what is our potato and our capacitor.

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