diàlegs

JUNE 2021 Nº 2

Revolution 4.0 is coming

A quality STEM education, guarantee for the future

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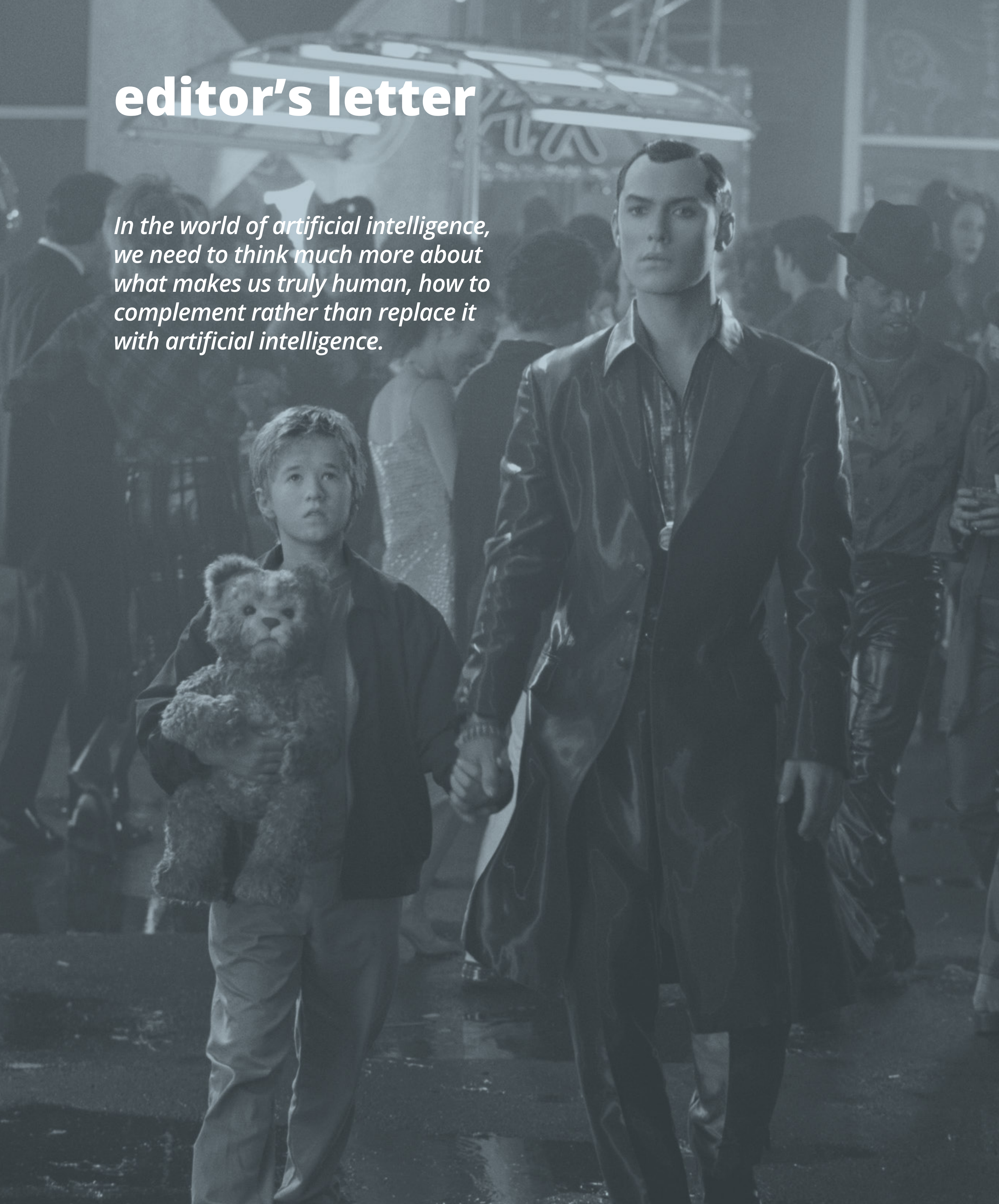
impuls educació

editor’s letter

In the world of artificial intelligence, we need to think much more about what makes us truly human, how to complement rather than replace it with artificial intelligence.



For science and technology with a soul

Ana Moreno
Director of Impuls Educació

Dear reader,

It is 20 years now since the release of Steven Spielberg's film *Artificial Intelligence*. The film poses a tremendous ethical dilemma: is it human to use technology to create humanoids to replace people, even in matters of the heart? A world immersed in exponential technologisation needs a progressive awareness of what is human, which guarantees the dignity of each person above any personal, social or political interests.

The director of education at the OECD, Andreas Schleicher, reflected in his interview for *Impuls: in the world of artificial intelligence, we need to think much more about what makes us truly human, how to complement rather than replace it with artificial intelligence*.

Spielberg's film presents a world devastated by climate change and lack of resources: science and technology have become the salvation of humankind, but the price is high: soulless machines replace people.

This second Impuls issue presents the scientific and technological development our world is immersed in. Our focus is the growth of humanity and our planet healthy sustainability, rather than promoting an unreasonable value of technology for its own sake or promoting a technological race whose ultimate goal is competing and winning.

David Cuartielles, the co-founder of Arduino, is very clear about this. Since his career began, he has been devoted to humanising through two essential tools in our 4.0 revolution: design and technology. When asked him about the experience of the covid-19 pandemic on Arduino, he immediately told us that he had decided to prioritise the good of people, employees, students, teachers rather than the financial goal. This is precisely the real success of Arduino, a quality technology for everyone to enjoy, without patents, but with the best design so that it adapts perfectly to each person-user.

Every article in this issue provides a different and complementary perspective to help us understand the complex world of improving science and technology education. We start with an international project, *The Relevance of Science Education* (ROSE -2002): it has significantly impacted all stakeholders and has just released a second edition. ROSE's achievement has highlighted the perspective of socio-emotional factors when facing the challenge of attracting students' attention to science and technology. The comparisons based on economic well-being level and gender are of particular importance: they help us understand that there won't be a more positive perception of STEM subjects and professions just by improving STEM teaching, but it is just as necessary as to address family, social and experiential factors, if not even more critical. As an example, we can mention the president of the Catalan Society of Technology (SCT), Nuria Salán, who remarked that knowledge of scientific-technological applications should be extended to aspects related to improving people's living conditions, such as safety, comfort, energy-saving, health and sustainability to attract the female sector. For real human progress requires science and technology with a soul.

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proyecto

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Anders Jidesjö (Mid Sweden University)

President of the Catalan Society of Technology (SCT)

Núria Salán

ROSES Project. Importance of science and technology today

What do teenagers think about their science class?



by Maricarmen Albás, Clara Blanch and María Pilar Almajano

According to the PISA 2015[1] report, boys and girls perform very similarly in science tests. It implies that cognitive ability in science is not gendered. However, around 5% of girls' value pursuing a career in science or engineering compared to just over 12% of boys, as shown in Figure 1. In the same report, the majority of students expressed a strong interest in science topics recognising the important role of science in their world. However, only a minority reported participating in science-related activities. In contrast to other large-scale studies such as TIMSS[2] and PISA, the ROSES project suggests that if we want to know what young students want to do in the future, we need to look not only at their cognitive dimension but also at their social and emotional dimensions: these are often the most important determinants of their final choice.

According to Núria Salán, president of the Catalan Society of Technology (SCT) and coordinator of the UPC's Gender Programme, we must bring technology closer to citizens by showing its fundamental role in social progress. The technophobia that, she says, still exists in our society needs to be broken: *Catalonia needs technologists, we want to have more boys and girls who opt for technology studies because the future will be technological or it won't be*. Fighting against gender inequalities in this field is also one of Núria Salán's challenges. For Salán, there is no single cause, and the main reasons could be related to a lack of role models and references. For example, she says, there is a lack of examples of STEM professional women who show themselves naturally in their usual tasks; on the other side, though, there are many examples of STEM boys (see the full interview at the end of the article).

HOW TO MAKE SCIENCE AND TECHNOLOGY MORE ATTRACTIVE TO YOUNG PEOPLE?

Science and technology education plays a key role in modern society as they are the engine of its economy and their relevance from a cultural and democratic point of view. For the OECD, for example, quality science and technology education is essential in a global, knowledge-based economy where technology is ubiquitous. For this reason, when PISA assesses the quality of an education system and the level of preparation of young people to successfully face their future, too, it focuses precisely on science and mathematics, in addition to reading.

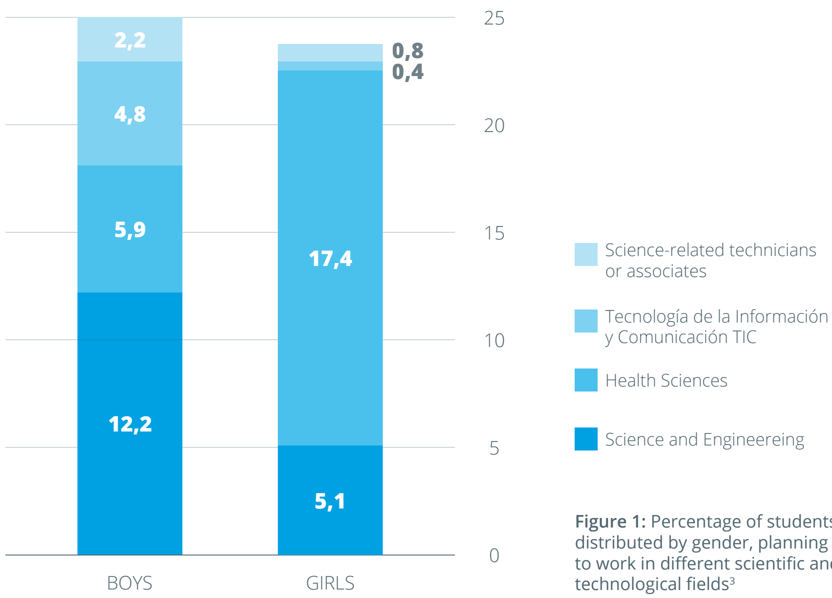

Figure 1: Percentage of students, distributed by gender, planning to work in different scientific and technological fields[3]

Since the last quarter of the 20th century, international initiatives have begun to emerge; they bring together the most diverse *stakeholders* under the same purpose: how can we make learning science and technology more attractive to teenagers, and in particular, how can we encourage them to pursue higher studies related to STEM (Science, Technology, Engineering and Mathematics)? IOSTE (International Organization for Science and Technology Education) is one of the most dynamic proposals. This UNESCO's NGO is recognised to promote science and technology education as a vital part of general education in all countries. Currently, it has participants from nearly eighty countries. It organises a biannual symposium that brings together many high quality, influential research papers and practical proposals from all over the world in each of its editions. Thirty-one countries participated in the last one, which was organised in Korea and held online. It was entitled *Transforming science and technology education to cultivate participatory citizenship*: the main objective was to promote the ability to generate public dialogue and debate and to be willing to take responsible action for sustainable development among young people in a world plagued by unchecked global warming, an energy crisis, health threats, new materials, etc.

In many countries with high PISA and TIMSS scores, interest in and attitudes towards science tend to be very low.

Svein Sjoberg is a professor at the University of Oslo with a PhD in Nuclear Physics and has been an active member of IOSTE since its inception and later its president. He is one of the most influential people in improving science and technology education worldwide. He has been involved in most European projects to improve science education and worked intensively in less favoured contexts such as AFCLIST (*African Forum for Children's Literacy in Science and Technology*). One of his significant achievements has been to bring to science and technology education the scientific rigour of a physicist coupled with an understanding of psychological and social factors. His work includes the social dimension of science education with critical studies on gender, social and cultural differences. One of his major concerns has always been the science education of girls and young women. Professor Sjoberg was one of the first to see that international comparisons of standards such as PISA or TIMSS needed to be integrated with international studies on attitudes towards science and its reactions. He was the first to become involved in global studies on the subject by leading the ROSE (Relevance of Science Education) project: one of the primary studies on the subject. This international research achieved broad participation and valuable results that were a significant step forward in all continents, including Africa and Asia.

In the educational systems of most countries, positive attitudes towards science and technology (S&T) are essential learning objectives, as is valuing science as part of the culture. However, in many countries with high PISA and TIMSS scores, interest in and attitudes towards science tend to be very low. This was of great concern to ROSE promoters who consider affective dimensions in science education as important as academic performance.

RELEVANCE OF SCIENCE EDUCATION. FROM ROSE TO ROSES

ROSE was a cooperative research project aimed primarily at studying how young people relate effectively to S&T. The main objective was to analyse factors influencing students' attitudes and motivations. Its main objective was to analyse the factors influencing students' attitudes and motivations. The study focused on

Professor Sjoberg was one of the first to see that international comparisons of standards such as PISA or TIMSS needed to be integrated with international studies on attitudes towards science and its reactions.

a questionnaire for 15-year-olds that could be applied to students from different cultures. It asked them about their experiences with science outside and inside the school, their interest in learning certain content, their views and attitudes towards science and scientists, their future aspirations or their feeling of empowerment concerning the challenges in their environment, etc. Researchers from all continents and nearly 40 countries took part.

The results were of interest to science teachers and researchers, national and international organisations such as UNESCO, the EU and the OECD, and numerous NGOs involved in supporting science education. Svein Sjoberg was invited to participate in numerous European initiatives: *Europe needs more scientists (2004)* provided a basis for the subsequent development of science education policies in Europe; *Eurobarometer* conducted a study on Europeans and their relationship with science and technology, the results of which were compared with ROSE, or *European Round Table of Industrialists (ERT)*, among others, and in the most representative international conferences, such as ECSITE, The Royal Society, ICSU, IOSTE or Eurycide (2010), where he presented the conclusions. Another consequence was the OECD's increased focus on STEM (science, technology, engineering and mathematics) disciplines as critical for development.

The 240 items of the ROSE questionnaire were classified into ten categories, some of which include:

- What I want to learn
- My future work
- Me and environmental challenges
- My science classes
- My views on science and technology
- My informal science experiences
- Me as a scientist

Some of the most striking results were:

1. Young people strongly agree that *S&T is important for society*.
2. In less developed countries, they strongly agree that *S&T make our lives healthier, easier and more comfortable.* In developed countries, they do not agree so much, especially girls.
3. In less developed countries they strongly agree that *new technologies will make work more interesting*. In developed countries, they do not agree so much, especially girls.
4. In less developed countries, they strongly agree that *science at school has shown me how important science is for the way we live.* In developed countries, they don't agree so much.
5. In developed countries, few young people want to be scientists, especially fewer girls.
6. Almost no girls want to work with technology in developed countries, and even boys are ambivalent, especially in Japan.

Almost a generation has passed since ROSE, and scientific and technological progress has means that the world and society are continuous transformation. There have been social developments, new addictions, new models and trends. How much have students' interests changed? In a world where social networks have changed the way we relationship and inform us, global environmental challenges are highly mediatised (Greta Thunberg) and a world wide pandemic has disrupted all their plans.

Figure 2: Countries where ROSES-2020 analysed results.

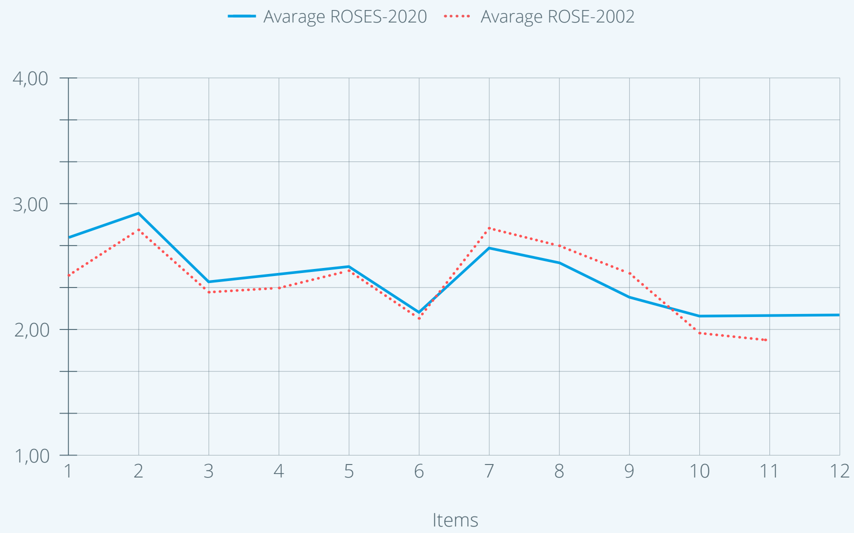

Figura 3: Comparison result of category F of the ROSE-2002 and ROSES-2020 questionnaires.

It is in this new context that ROSE Second (ROSES) is born. This time Professor Sjoberg passes the baton to three Swedish researchers: Magnus Oscarsson (Linköping University), Anna-Karin Westman and Anders Jidesjö (Mid Sweden University). The number of participants in the new project is growing, as shown in Figure 2, reflecting the situation in April 2021. It continues to grow due to widespread interest. ROSES is intended as a continuation of ROSE. The main objective is to update the empirical evidence in the context of the new situation and to inspire significant improvements. Therefore, most of the questions remain the same. The aim is to study how ROSES results relate to ROSE, to what extent there is a progression or regression, what impact ROSE had and what more could be done to improve S&T education.

PRELIMINARY ROSES RESULTS AND FIRST COMPARISONS

Spain is one of the participating countries. In Catalonia, more than 800 students from 11 schools in Barcelona, Girona and Tarragona have already participated. Figure 3 shows a comparison of 12 items belonging to category *My science lessons*, of the ROSES questionnaire. The graph shows that Catalan students better perceive their science classes than the average Spanish data collected in ROSE-2002[4].
On a scale of 1 to 4, students were asked to what extent they agreed with the statements about *My science lessons* are:

1. *Science is a difficult school subject.*
2. *Science is an interesting school subject.*
3. *Science lessons have opened my eyes to new and exciting work.*
4. *Science is more enjoyable than most other school subjects.*
5. *The things I learn in science lessons will be useful in my everyday life.*
6. *Science lessons have made me more critical and sceptical.*
7. *Science lessons have increased my curiosity about things that we cannot yet explain.*
8. *Science lessons have shown me how important science is to the way we live.*
9. *Science lessons have taught me how to take better care of my health.*
10. *I would like to become a scientist.*
11. *I would like to get a job in technology.*
12. *Science lessons have helped me to understand sustainable solutions in my everyday life.*

As can be seen, the results, 18 years apart, follow the same pattern. The highest scores are obtained in 1, 2 and 7: they reflect the difficulty, interest and usefulness of science class. On the other hand, the lowest scores in 6, 10 and 11 reflect the intention to be a scientist or get a job in technology.

Norway pioneered the questionnaire application and presented its results at the IOSTE symposium in Korea in February 2021. Figure 4 shows a comparison of preliminary results from Catalonia and the Nordic country, about 4 items related to attitudes in science classes.

These first results obtained reflect a similar trend in the interest shown in the subject of science (Item F2), close to 70% of adolescents. The trend, therefore, seems to be maintained, despite the changes and efforts made by the education systems.

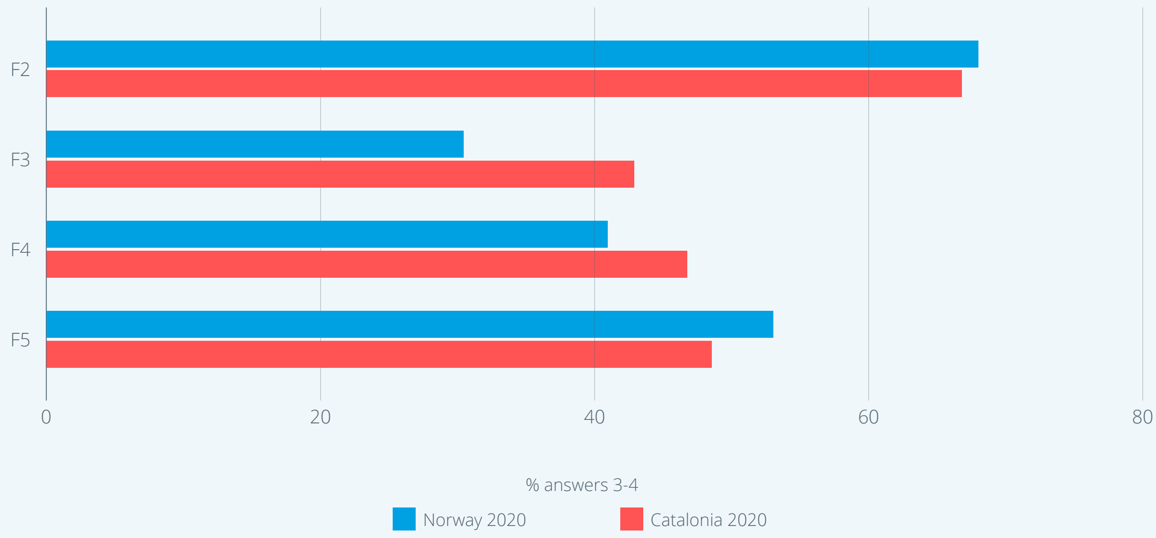

Figure 4: Preliminary comparison between Norway and Catalonia in ROSES-2020.

INTERVIEW WITH THE ROSES PROJECT DIRECTORS

What impact did ROSE have on the educational systems of the participating countries?
ROSE surprises in several ways, which explains its success. One key result is that students are interested in science and technology, and the interest is linked to specific content. Another result is that students' interest seems to be related to social development, and the trend is international. In general, the more modernised a country is, the less interest students show. The connections with performance are more challenging to understand. There were different reactions in different countries. Each country decided how to make use of this evidence and worked on policies and reforms. For example, in Sweden, we tried to incorporate the affective dimensions in the 2011 curriculum reform. However, it was difficult to make a difference. Beyond the participating countries, I would say that, for example, in PISA, there was a discussion about the importance of measuring *affective attitudes*, a debate that is still going on. Other organisations and NGOs have shown interest in the results, and many stakeholders have used them.

What motivated to the continuation of the ROSE project?
Worldwide colleagues contacted Svein Sjoberg about ROSE and wanted to know more about changes and new research. This led him to propose an expert roundtable at the IOSTE conference in 2016. As a result, we were asked in Sweden to continue the work and create a second ROSE study. Given that many things happen in different societies and globally, such as climate change, conflicts, catastrophes, social networks, etc., together with, for example, science and technology campaigns, several colleagues argued that the results would have changed. It is expected that youth culture, modernity or other situations influence the results. We want to investigate in order to draw conclusions empirically substantiated statements. Since many are interested in this research, we consider it worth a try.

What are the differences between the questionnaires of the two projects?
In ROSE, most countries collected data using paper questionnaires. Although many students found the questionnaire time-consuming, it worked. Today, most countries collect data in a digital mode. In a digital mode, most people interrupt it if they find a questionnaire too long. For these reasons, from many worldwide colleagues expressed the wish to shorten the number of items in the questionnaire. We had several discussions on how to do this, especially in the ROSES advisory board. After methodological considerations, we applied a statistical method that helped us optimise and improve the questionnaire to add some new categories and items.

Could you tell us what trends you observe in this second study?
These are the first results, and they are preliminary. However, a first general impression is that the situation resembles that of the early 2000s. We are now analysing it further and will be able to see some trends, which we will publish and

I call for the visibility of models of proximity, such as alumnae of secondary schools everywhere, who now have a STEM profession, regardless of how they have achieved it.

communicate in the following papers. There will probably be different situations in different countries.

How to make science learning more relevant to girls and young women?

It is essential, but we are not sure about causality and there is a risk that we will not address the real causes of the problems identified. For example, there is much evidence pointing to the importance of early childhood and the primary education, which makes us suspect that projects at the secondary level may be too late and unsuccessful. However, we need more evidence and practical experience before giving recommendations.

The Roses Project Directors:
Anna-Karin Westman
Magnus Oscarsson (Linköping University)
Anders Jidesjö (Mid Sweden University).

INTERVIEW WITH NÚRIA SALÁN

Why do you think so few girls choose to study STEM careers?

There is no single cause, and the importance of each one varies depending on the environment (economic, social, family, ...). The main reasons lie in a lack of role models and references. There is a lack of STEM professional women who show themselves naturally and generally in regular tasks. At the same time, there are examples of STEM boys. There are STEM women who are quickly identified. However, they are usually *impressive* women (Nobel Prize winners: Marie Curie, Margarita Salas or professors: Anna Navarro-Schlegel), and this makes a *normal* girl, with *normal* grades, might feel outpaced from those models. It is crucial to give visibility to women inventors without a university education: it would make clear that having an excellent education is not essential to be creative or inventive. However, it is better if they have it. I call for the visibility of *models of proximity*, such as alumnae of secondary schools everywhere, who now have a STEM profession, regardless of how they have achieved it.

Family environment is another very influential factor. So, it is quite likely that a girl born in a STEM trained family may decide to do a technical university degree after finishing her chosen technological training cycle. Finally, another factor sometimes turns out to be the strongest: the lack of *training/information* of teachers in the technological field and the multiple professions developed from STEM training. For example, very few teachers come from a technological baccalaureate. Not having knowledge or a particular passion for STEM creates clichés and ignores the more human profile of technology (design of medicines, food and medicine preservation systems, robots that make impossible surgeries possible, assistive robotics, ergonomics, comfort, sustainable design...). Therefore, it would be necessary to include technology content in general teacher training.

These three reasons often combine, and when they happen to converge at the same point, we find ourselves with a *STEM black hole*.

What would you say to our young people (boys and girls) to encourage them to choose STEM disciplines?

I would tell them that this present 21st century is the one of science and technology; the coming decades' professions in demand have not yet been written but will be STEM-related professions, and unless they develop a minimum of competencies in this field, they will remain spectators and will not be designing their own future. I would also tell them that the *bad reputation* that precedes STEM is not accurate. Mathematics is not complicated but exciting: it only needs to be well explained. Although it may be perceived as a little more complicated than other disciplines, it is not unattainable training. The gratification that comes with having the training to keep up to date is priceless.

What do you think are students' attitudes and perceptions related to science?

They may believe science is for intelligent people, excellent grades, with a socio-economic profile far removed from low incomes. However, none of these three is strictly true. Throughout the history of humanity, science has helped us understand the reason for everything and justify surrounding phenomena. From this understanding and knowledge, we have designed remedies, improvements and solutions to live better. If nobody had dedicated themselves to STEM, we would not have mobile phones, laptops, wifi, vaccines, or dehydrated food... All the surrounding comfort is, to a

There is much evidence pointing to the importance of early childhood and the primary education.

With a STEM profile, one can participate first-hand in the development and construction of a better world.

large extent, the result of good STEM actions. What remains to be designed and built is in the minds of the rising generations.

What factors can significantly affect science learning?

Teachers should have a positive and assertive view of science. If they have science internalised, they will pass it on with passion.

We are *selling* the students successful role models who succeeded in STEM professions. However, offering a vision of the self-taught genius like Steve Jobs does not help, nor does the *pressure* about what to study or the right time to finish studies in order not to be a failure; there are young people who need a different pace.

There are options for gamification or learning based on actual problems, which help a lot to incorporate science from its application examples to see its usefulness. The teaching staff's complicity and passion are necessary.

What factors can significantly affect science education and STEM vocations?

Examples of *complex* technologies that make our lives easier and more comfortable could help. From these examples, and going backwards, unravel the necessary knowledge for developing these technologies and, by doing so, identify the skills the people who developed them had.

Moreover, examples of sectorisation of technology application could also be used: advances in mechanics are easily directly related to powerful, fast cars; other aspects have also been significant (safety, comfort, ergonomics, energy-saving) considered as *second-class achievements*. The power of a car attracts boys, but girls feel more empathy for its energy efficiency. The same example, with different nuances...

It is often said that with a STEM degree, one will not be short of work. Furthermore, it is true. With a STEM profile, one can participate first-hand in the development and construction of a better world. So are you going to miss it?

Clara Blanch Ricart holds a degree in Civil Engineering from the Polytechnic University of Catalonia (UPC). She studied a Master's degree in teacher training in Mathematics and Computer Science at the Valencian International University (VIU). Since then, she has worked as a mathematics teacher in secondary and international baccalaureate. She has been part of the Impuls Educació research team since July 2020. Currently, she is a PhD student in Engineering, Science and Technology Education at the UPC and co-directed by the University of the Balearic Islands (UIB). She is coordinator in Catalonia of the ROSES-2020 Project together with Maricarmen Albás.

Mari Carmen Albás Bollit is a Telecommunications Engineer from the Polytechnic University of Catalonia (UPC). She is currently a PhD student in Engineering, Science and Technology Education at the UPC and co-directed by the UIB. She has been a teacher of Mathematics and Technical Drawing at the Vall School (Institució Familiar d'Educació) since 1996. She has been part of the research team of Impuls Educació since June 2020. She implemented the international e-Twinning programme, the use of the moodle platform in the school and was a pioneer in the use of mobile devices in the classroom.

María Pilar Almajano Pablos holds a PhD in Chemistry. She has worked in secondary education for 12 years. She has been at the UPC for more than 20 years, where she is currently working. She has two active lines of research: natural antioxidants and the improvement of student learning (both at secondary school and university). A regular collaborator of the ICE of the UPC since the beginning of her professional career, she currently teaches subjects and workshops to UPC teachers and future secondary school teachers (specialising in technology).

Notes

[1] The PISA (Programme for International Student Assessment) report is the OECD's global study of academic performance in mathematics, science and reading.

[2] TIMSS (Trends in International Mathematics and Science Study) international assessment of mathematics and science literacy of fourth and eighth-grade worldwide students.

[3] Source: *First Class Building a Quality School for the 21st Century* https://doi.org/10.1787/9788468050126-es

[4] *The Relevance of Science Education II: The voices of Catalan students in their science classes. Preliminary results*

the report

Àgueda Gras-Velázquez is the Science Programme Manager of European Schoolnet (EUN). As Head of the Science Education Department at EUN, she oversees all STEM projects in which EUN is involved. Additionally, she is in charge of the day-to-day management of *Scientix* (the community for science education in Europe) and coordinates EUN's Ministries of Education STEM representatives Working Group. In her 12 years at EUN, Àgueda has been involved in more than 60 EC funded projects and 18 private funded ones. Before joining EUN in May 2008, she worked as an independent eLearning Professional as Tutor, Content designer, IT manager, Administrator, Project Manager and Consultant for international projects. She has co-authored several papers in Science Education Research and has a PhD in Astrophysics from Trinity College Dublin, carried out at the Dublin Institute for Advanced Studies in Ireland.

Scientix

The community for science education in Europe

by Maria Font

INTERVIEW WITH ÀGUEDA GRAS-VELÁZQUEZ

What is Scientix?
As the community for science education in Europe, Scientix aims to promote and support the collaboration between teachers, education researchers, policymakers, and other education professionals in STEM across Europe. Since 2010 Scientix has developed in such a way that today it provides European teachers with a platform to expand their own knowledge of STEM subjects by connecting with other fellow teachers and getting inspired by all types of STEM education projects. This precious exchange takes place directly on the Scientix platform, where teachers can find new ideas for their classes through the resources' repository and online training, webinars, and community practices the projects offer. As part of its core mission, Scientix also functions as a bridge that connects European teachers to other professionals in STEM fields by creating the space for them to co-organise events and present the projects they are carrying out with their classrooms at Scientix conferences. Finally, Scientix allows policymakers to stay up to date with the most recent theoretical and practical developments of different STEM subjects, influencing future national strategies that might be adopted in science education.

How did Scientix start, and how did it evolve?
Scientix was born in 2010 thanks to the European Commission's General Directorate for Research and Innovation that wanted to ensure that all materials and results from public-funded projects did not disappear once the projects finished. It has developed in three phases. Between 2010 and 2012, the project created a space where European STEM projects could be presented by developing an online portal and organising several workshops for teachers. Between 2013 and 2015, Scientix contributed to developing national strategies promoting innovative approaches to science and math education through the creation of a network of National Contact Points (NCPs). Finally, between 2016 and 2019, Scientix expanded its panel of Scientix Ambassadors and professional development opportunities. Scientix is an initiative of the European Commission (EC); since its inception, it has always been proudly coordinated by European Schoolnet (EUN), and it is everybody involved in Scientix and STEM education that makes it the success it has become.

Scientix 10 years later
During the last ten years, I could experience the value Scientix brought to STEM education across European schools. Besides the positive feedback we have received from many teachers who attended workshops offered by Scientix, this community has proven itself to be an incredible tool for professional networking and knowledge sharing. When speaking about these achievements, my reference extends beyond those actions EUN organises

Scientix allows policymakers to stay up to date influencing future national strategies that might be adopted in science education.

and is primarily responsible for (e.g., Scientix national conferences, publications, reporting, etc.). The potential of Scientix became firstly tangible to me when witnessing how European teachers used the community to snowball into similar projects, not because EUN asked them, but out of their own will. For me, it is in these teachers' desire to connect and share their experiences with other professionals for the sake of expanding the body of knowledge surrounding STEM where the success of Scientix lies. In this sense, Scientix is a catalyser – it does not speak about itself, but rather about the effort, achievements, and struggles of many teachers who, thanks to the community, actively contribute to feeding the flow and exchange of STEM knowledge.

A specific case of success of Scientix

One of the main achievements of Scientix is connecting all these teachers Physics, Chemistry, Primary education, Mathematics, Biology, Engineering, and even non-STEM subjects. Thus, creating a real *STEM* community that ensures no teacher feels alone in front of the problems of teaching.

In 2010 when we started Scientix, it took us time to find 30 teachers willing to dedicate time to sharing their expertise in STEM education with everybody else. Accept that whatever they created would be freely available for all. Since then, we have moved to a Scientix Ambassadors teachers' panel with 90 ambassadors in 2014 to 400 in 2018 and to 850 in 2021, with many more just missing out on the cut due to the different requirements to take this role. These teachers have become beacons of ideas, support and collaboration.

In these years, we see teachers across Europe going out of their way to organise different workshops under the Scientix umbrella on topics from remote labs to the Flipped Classroom concept, Robotics, practical experiments or Nature-Based solutions. They organise short workshops, long ones, online, face-to-face. Whatever format you need, Scientix Ambassadors find a way. It is not about *why cannot it be done for them* but *how can we make it happen*.

I have seen teachers from different countries sit together and come up with a project over dinner. I have observed how teachers who met at the beginning of Scientix and struggled to communicate in English write together several European Commission projects three years later, which they got funded. I have received emails from many, many many teachers which after meeting other STEM teachers from across Europe, are now collaborating, exchanging, meeting...

In 2019 the European Commission called for an award to the best Horizon 2020 funded projects. We decided to submit Scientix for consideration at the time. One of the requirements was to provide a couple of support letters showing the achievements. It was a Friday, and I wrote to the Scientix Ambassadors to get 2 or 3 of these letters. I spent the weekend collecting over 170 letters from teachers across Europe and beyond sharing their experiences and how Scientix had helped them develop, different actions taken at school, local or regional level to improve STEM education, networks created, new projects and activities. Scientix did not win the formal award, but we achieved more than we ever imagined. The Scientix Community for science education in Europe was alive beyond anything we had planned. Scientix is there to provide a community for all and to get the knowledge flowing; to get the information travelling (what you do not find in your country/project/class, you can find abroad/elsewhere); to ensure that no project works by itself; that no STEM centre or organisation needs to start from scratch and no teacher faces alone the arduous but most needed task of getting kids to know, like and even dream about science.

This community has proven itself to be an incredible tool for professional networking and knowledge sharing.

panorama

"There is no education system in the world that achieves excellence without addressing the diversity of needs of its students."

INTERVIEW WITH ANDREAS SCHLEICHER

Andreas Schleicher (Hamburg, 1964) is one of the most influential people worldwide about the quality of educational systems and an education statistician and researcher. He leads the OECD's Education and Skills section since 2012; He previously was Director of the Department for Education Indicators and Analysis. He coordinates the PISA (Programme for International Student Assessment) report, which covers nearly 90 countries.


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“Quality in education is about teaching students develop a reliable compass to navigating a world we that cannot predict.”

by Ana Moreno

The numerous studies over the last 20 years of PISA have provided a large amount of data that allows us to predict the success of certain educational policies with certain guarantees. What do you consider to be quality in education in the current situation, and what characteristic features should an educational system have?
For me, quality in education means that students are prepared to live with themselves, with others and with the planet. That they are able to think for themselves, but also to collaborate. Quality today is knowledge, competence, attitude and values. I believe that in the world we live in, quality in education is not about teaching students something, but helping them to develop a reliable compass and the tools to navigate with confidence in a world that we cannot predict, a world that is uncertain and volatile.

There are still many people who look askance at the change of focus in education from content to competencies. They fear a loss in the quality of education. What should be taken into account in this transformation for a positive transition? What would you say to those who fear a loss in basic language and mathematics skills or simply a decrease in knowledge?
I think the need for skills comes from the world we live in, the modern world. It no longer rewards you for what you know; Google knows everything. It does it for what you can do with what you know.

Can you extrapolate what you know? Can you apply it to a new situation? This is what we have to take seriously.

At this time, it is very important to ask how to make the transition. It is clear that we cannot change our curricular paradigms radically from one day to the next and expect immediate results. This is a gradual change that involves different learning environments and ways of teaching, where learners are not passive consumers of knowledge but rather work actively to develop the knowledge they experience. It is not about eliminating the value of science, but about how we can improve the teaching of physics or chemistry so that young people think like scientists. When you design an experiment, can you distinguish between scientific and non-scientific questions? This is the foundation of science. This is how students acquire relevant knowledge. If we teach from the surface, they don’t understand what science is, and it won’t help them in the future when that knowledge is different. This is a bit like what happens in Spain. You have a curriculum that teaches young people a lot of things in a shallow way, a mile wide and an inch deep. With history, it’s the same; the competition doesn’t eliminate history: it makes the transition from learning names and places to being able to think as a historian does. In this way, they can understand how a society emerges, how it develops and advances, and sometimes how it reveals itself in changing contexts.

Mathematics is very important in competence-based learning. But it is also not about teaching how to calculate an exponential function; it is about helping students understand the concept, the nature of an exponential factor. In the pandemic, we have had big problems with this. As human beings, we are born into a linear world, time is linear, and that

Students should be helped to understand the fundamentals of the most relevant ideas in each discipline. Less things with more depth to avoid superficial teaching.

makes us comfortable. Suddenly a virus appears that behaves exponentially, something that we have no experience of, but the world of mathematics can open us up to that experience and understand it. If we only teach the surface, students learn to calculate something that a computer can calculate much faster.

I think the important thing is not about more or less knowledge, but about helping students to rise beyond their knowledge by understanding the fundamentals of the relevant ideas in each discipline. This means teaching less to a greater depth and avoiding superficial teaching.

This puts a lot of effort on teachers; it is much easier to read a textbook than to provide pupils with a real conceptual understanding of the content. However, we can look at countries that are doing really well. If you go to a classroom in Spain, you will see a teacher teaching 16-17 maths problems in an hour, so students get a lot of practice on one type of problem. If you go to a class in Japan, the teacher works on only one problem in an hour. The teacher and students analyse the problem from different perspectives and ideas, and by the end of the lesson, the students have understood an idea, made it their own and can extrapolate from it.

This way of teaching is much more difficult. It is not about making a radical transition. It is about gradually empowering teachers, supporting them, and moving from a model where students are passive recipients of knowledge to one where they are active co-creators. This is the most important thing.

You are a great advocate of the idea that quality education for all is possible. How can schools make progress towards this goal without having a lot of large resources? How do the education systems that achieve it do so in order to attend to the most disadvantaged without improving the results of the rest?

If you look at the most advanced education systems, you see that pupils' success is little related to their socio-economic background. You see much more stable performance in Estonia, where the closest school is the best. There is not much variability in the performance of the school, nor in the performance of pupils according to their social background.

There is an explanation for this. The traditional system is based on a single model applied to all students. This works well for some students but works poorly for others. What high-performing education systems understand is that different students learn differently, and they try to cater for that diversity with differentiated educational practices, giving students different paces to engage in their learning and make progress. There are different learning styles and special needs.

In Spain, 8% of their pupils are thought to have special needs and need to be treated separately. In Estonia, Denmark or Finland, they think that 100% of their pupils have special educational needs. All pupils have special talents, and we need to give them additional support so that they can develop them. There are pupils who have difficulties in one area or another, and we need to give them extra support. This is very demanding for teachers; they need to understand how different their pupils learn. They need to be able to master a wide repertoire of different pedagogical strategies.

But today, we have many good

examples. We can safely say that there is no education system in the world that achieves excellence without addressing the diversity of needs of its students.

In Spain, there are many students who fall through the cracks at the lower end of the spectrum. The mentality of the education system is still that if you don't succeed in the system, we let you repeat. But this is very expensive for Spanish society. You will have to pay 25 to 30,000 Euros for each repeater because you will have to wait a year for them to enter the labour market and pay taxes. So what they do in high-performing education systems like Japan, Singapore, Finland or Estonia, is to think differently, to give the school extra resources so that they can provide additional support and ensure that they avoid the risk of repeating as much as possible. In this way, resources are invested in understanding and nurturing talent and not in encouraging repetition.

We need to grow the extraordinary talents of ordinary pupils. It is not about sorting students who are very good at everything from those who are not good at everything. I think this is an achievable goal, and I see many education systems that are getting closer and closer to achieving it.

In 2019, the OECD was proposing a renewal of the competency framework for the 21st century. The idea of ensuring lifelong learning is strongly reaffirmed in it. What learning or competencies are basic to ensure lifelong learning?

I think the key is curiosity. The lucky thing is that as human beings, we are born with it; if you have a three-year-old daughter or son, they are extremely curious. They ask about everything, and they want to do everything themselves; they learn, and they make mistakes, and they try again: they are very resilient. If a good education system tries to nurture and enhance this curiosity, this hunger to learn, this love of learning, then we will create lifelong learners.

The challenge of lifelong learning is not an opportunity. The challenge is the idea that every day I walk around trying to become that better version of myself that can prepare me for new jobs that have not yet been created, to use technology that has not yet been invented, to solve social problems that we can't even name yet. I think this disposition towards learning is very important. If, as a teacher, all you get is that your students leave school with this curiosity for life, you have achieved a lot. If, on the other hand, you educate for very specific knowledge and they don't update that knowledge and skills, they will soon find themselves lost because the world is changing so fast. You have to be willing to try new things, to question the wisdom of our time, not just reproduce it. It is also very important to have a growth mindset, to think that my success depends on me, on my effort, not on my inherited intelligence, the ability

Change is not a choice; we must make sure we educate young people for their future, not for our past.

to solve complex problems, and the willingness to navigate ambiguity and make decisions in a context where we cannot understand all the elements and cannot take a step back.

Just yesterday, the OECD published a new report showing that young people have difficulty in distinguishing fact from opinion and also in dealing with conflicts of interest or finding their own way of thinking.

Another issue is that the willingness and ability to mobilise cognitive, social and emotional resources in learning, where emotional and social aspects are increasingly important.

On the other hand, in the world of artificial intelligence, we need to think much more about what makes us truly human. How to complement and not replace artificial intelligence. I think this is an aspect that education needs to pay more attention to. I think good teachers do this all the time. These are, for example, the teachers that young people will remember from the pandemic. Those who took care of them, who understood who they were as students, who they wanted to become, who helped them realise their dreams and their passions, so I think this is very important.

The PISA programme introduces new competencies every few years, such as cooperative problem-solving in 2015, global competence in 2018, and creativity in 2022. How can an education system introduce innovations so quickly, and when will a *computational* competency such as programming be introduced?

I think we should ask the question the other way around. In a rapidly changing world, how can we make education adapt more quickly? Change is not a choice; we must make sure we educate young people for their future, not for our past. The question should be how we can make that transition.

Computer programming is very important today, but will it be important tomorrow? It is very difficult to say. I think it is very risky to try to teach young people today's techniques to solve tomorrow's problems.

It matters more whether students understand computational thinking. This question is already being incorporated into the next mathematics assessment - do you understand what an algorithm is? If not, you can become a slave to an algorithm very quickly. Programming for me, however, is a technique of today. I think that in education, we run the risk of jumping to the next type of technique that seems important today, investing a lot of effort and then, ten years later, we find that it's a dead end.

In a way, I think that in reference to the question about the future, we will probably be expected to be less instrumental in our approaches to education. In the past, we used to learn to work, and we invested our efforts in that, now learning is the work. I think this is a very important transition. We can no longer simply prepare people in a specific set of techniques to succeed in their lives. I think we really need to give them the tools to find their own way.

The pandemic has thrown the world into turmoil. The urgency to solve complex problems creatively and in a short time has shown that we are entering the depths of the age of innovation at full speed. How do you think this situation should be tackled from a quality education perspective?

Yes, it is true that the pandemic has been profoundly disruptive for education. The future will always surprise us. I don't think we can predict a single future. What we can do is think about different alternative futures and ask ourselves what the implications are. If we are prepared for multiple futures, we will be more agile and more prepared for what comes next.

I think this is what the pandemic has really shown. Students were able to learn on their own, where they were used to working with good technology, they had continuous social contact at school, and parents who were interested in their learning. The pandemic was perhaps even an interesting experience, and they even found a lot of new learning environments and resources.

But for students who *used to be spoon-fed by their teachers*, for teachers who worked in a very industrial kind of work organisation, suddenly, the world came crashing down.

In a way, the pandemic teaches us that in the future, having quality

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education means having much more responsibility on the front line. Less reliance on hierarchical structures where we look upwards.

Micro-managing a kind of realities where we look more outwards, where students collaborate, where teachers work professionally and are united and work very much connected to each other. I think this is what we really, really need to learn to make our education systems flatter, more collegial, more collaborative and less reliant on top-down prescription and direction and accountability. It is very important to have an education system that has more creativity and accountability in the classroom, in the school, on the front line, where teachers teach but also do other things. A good teacher also needs to be a good mentor, a good coach, a good designer of innovative learning environments, a great researcher in a technological world.

Scientists have a central part in this, it's about scientific innovation, but it's also about social innovation. I think they are like two sides of the same coin. In addition to great engineers, we want engineers who make ethical decisions. Artificial intelligence will give great power to most people, but it will not take away their responsibility to distinguish what is right and what is wrong, what is true and what is not.

In the past, you could teach someone technical skills, and that was enough. Today, I think you need to equip young people with a fairly wide range of technological and social innovation skills. The two need to go hand in hand, as we have seen in the pandemic.

Technology has not saved anyone in the pandemic; technology has not done the learning. In fact, what we discovered in the pandemic is that learning is not a transactional process; it is relational, a social phenomenon.

And I think this is where the scientific perspective and the social perspective will really become more closely integrated in the future. We used to distinguish between what was learned for life and what was learned for work. Today I'm not so sure that that distinction is really relevant.

Technology is already omnipresent in all areas of human life; today, a child can learn to use a mobile phone, a tablet and even a computer without knowing how to read or write. From your point of view: What role should technology play in the education of the new generations?

I think technology has a lot of potentials. Artificial intelligence can help make learning much more regular, interactive and participatory. When you study mathematics on a computer, it analyses how you study, finds out what you are interested in, takes you where you need to go to improve. I think artificial intelligence is clearly a power that can improve the transmission of knowledge. Learning analytics can now help teachers better understand how different students learn in different ways and then understand how to change strategies or approaches.

Big data in education also brings a lot of potential learning. But, you know, the technology is always a social process. I think learning can empower students and teachers, but it cannot replace the social process; it cannot replace the role of a teacher. Although, the role of the teacher changes and evolves and improves the understanding of your students. It cannot be replaced in educational intentions, the understanding of where your students have their talents, how to help them develop their talents, to understand, or what would help a social purpose. I think technology can complement, but it should always be the human dimension, the people skills first. The biggest fear we should have is having a great smartphone and not having bad skills, being a slave to technology, to algorithms. I think we have to keep the balance between technology and human skills to create very meaningful synergies, and we have to think about how they can

complement each other, not replace each other. In a way, I think the main investment in training young people in this sense has to be the human skills to use technology.

It can also help teachers to design really good planning environments where the best technology is probably the technology that is totally invisible in the classroom.

We are almost at the end of our interview, and I would like to talk about something that you yourself have once considered a pending subject in many educational systems: the incorporation of ethical values into the curriculum as educational objectives. Why do you consider it so important, and what values do you think are the most necessary at this time?

In the world we live in, the most important contribution to education is to give pupils a reliable compass, which gives them a sense of what is right and wrong, what is good and what is bad in this context. In the past, you could ask the people around you, the older people who knew the world very well and could tell you all the answers; in today's changing world, that is very difficult. Many parents don't understand that their sons and daughters need to make those kinds of judgements for themselves.

Technology doesn't help either; it's a great amplifier, an accelerator. It accelerates good ideas and good practices in the same way that it accelerates bad ideas and worst practices so that values become really critical.

A good teacher also needs to be a good mentor and coach, a good designer of learning environments and a great researcher.

In the past, we used to put values at the bottom of the system; we thought, let's teach knowledge first, and at the end, we talked about values. In the future, we have to put values at the centre of what we teach and then think about knowledge and skills as possible ways to illustrate those values. For example: in sport,


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In the future, we need to put values at the heart of what we teach, and then think about knowledge and skills as possible ways to illustrate those values.

in the future physical education is not just about being more athletic, but being able to take responsibility for oneself. I think we have to put values at the centre and ask ourselves to what extent our school subjects are based on those values.

On the question of knowing which values, this is a more difficult question, and I think the cultural and social context of a country plays a very important role.

But I think there are some really important ones. Plurality is a reality of our societies of the world we live in. If we understand each other as human beings, we can appreciate different ways of thinking, different ways of walking, understanding each other.

We can teach our own religion in a school, but if we understand other religions, if we can really look at the world through different lenses and perspectives, we can relate better.

We wish everybody had those values, but I think the question of the nature of values is something that is probably very difficult to answer from the outside. For me, the problem is that if people are not able to find answers for themselves, of what is right and what is wrong, and to navigate the ambiguity, I think in today's world, they will hardly find resources from the outside.

Finally, I would like to ask you about teachers: what do you think are the key competencies of a teacher today, and what are the key competencies of a school head?

Obviously, what we expect from teachers is that they have a real passion and a deep knowledge of the subject. Secondly, we want teachers to understand how each student learns differently from a deep pedagogical sense. They should understand their students and work with them. Finally, I think they should strive to understand their students as people, to know their context, where they come from, how they can help them find their way in their own lives. But that's just a starting point to be a good teacher: you have to help every student succeed, understand the diversity in the classroom dynamics, be a good researcher, find new methodologies with the teaching team, be a good team player in your school, observing other teachers' classes and working with them to contribute to the profession.

But nowadays, the school must be a place where everybody learns, students, teachers, parents, and as a teacher you have to participate in that process, you have to give back to your school what you know and help others to succeed as mentors, as pupils, etc. A teacher has to take charge of his or her profession all his or her life.

The first thing a school leader must learn is that it is not about teachers doing what he or she tells them to do but about collaboration. What decides success is helping teachers to grow, develop and be connected to the outside world.

I may not be able to pay them more, but I can make their work more intellectually engaging. I can engage communities, attract parents to the school and tap into other interesting resources in the community. I can do many things as a principal to make the school an attractive place for everyone, where students, and each other, are trusted. Trust creates an environment where people feel comfortable working. Much can be done to create an enabling school environment for teachers and make the school a place that supports their continuous improvement as teachers and educators.

Spotlight

education and STEM

by Ángel Vázquez and
María Antonia Manassero

Science and technology literacy, thinking and STEM development

The science of scientists must converge with the science taught in schools to make it accessible.

Education is an activity where context is as important as the body of knowledge it conveys. Individually, the context is determined by the perennial developmental needs of human beings (physical, psychological and relational); socially, globalised knowledge societies have a framework steeped in science, technology and innovation as critical factors of social and occupational development. In this context, science education must contribute to the integral development of responsible and educated citizens, boosting their capacity to adapt to globalised requirements and changing needs in the personal, social and labour spheres. Delors defined those exigencies as learning how *to know, do, be* and *live together*.

Research in science didactics at different educational levels is subject to the tension between tradition and innovation to achieve a significant contribution to these goals, providing the concept of scientific (and technological) literacy - STL - for all as one of the most relevant in recent years. STL is seen as consisting of three components: scientific and technological concepts and processes (*knowledge and know-how*), meta-knowledge about how science and technology construct and justify their knowledge and artefacts (*scientific know-how*) and social justice in STL for all (equity, access, etc.).

Research in science didactics is subject to the tension between tradition and innovation, providing the concept of scientific (and technological) literacy.

Specialists differ in their conceptualisations of ACT. For example, coinciding with the European and Spanish educational framework, the PISA programme (OECD) proposes ACT as the vital competence for understanding scientific and technological practice in the natural world -including science and science-based technology-: ATC plus its three sub-competencies: explaining phenomena scientifically, evaluating and designing scientific investigations, and interpreting data and evidence scientifically. All three operate on conceptual, procedural and epistemic knowledge. Epistemic knowledge refers to how scientific practice is and how it works: the status of scientific conclusions and the meaning of foundational terms (e.g. data, explanations, hypotheses, laws, theories, etc.), and coincides with the second ACT component.

SCIENCE AND TECHNOLOGY LITERACY FOR ALL

Teachers teach the core curriculum in their classrooms (competencies, objectives, content, assessment criteria), which involves making important didactic decisions (resources, methodology, activities, timing, assessment, etc.). Didactic content knowledge (TOT), or professional teaching knowledge, summarises teachers' competence to develop the curriculum; it involves the ability to dynamically combine scientific, didactic and psycho-evolutionary expertise, together with procedures, attitudes, and values achieve effective and coherent professional performance-oriented to ACT.

Scholars break down teacher TOT into sub-competencies, which are concrete and interactive with each other: knowledge of a subject and its curriculum, curriculum planning, classroom management, assessment of learning, inclusion and equity, community engagement, professional development, digital skills, linguistic communication and ethical commitments. Some authors propose the concept of didactic transposition to describe the transformation of scientific ideas by the TOT to make them teachable as ACT in school science; consequently, school science is epistemologically distinct from the science of scientists.

Teachers are free to make many developmental decisions, such as teaching methodology(ies). Of course, didactic research must inspire these choices, but we also know that teachers' beliefs are crucial and give rise to innovative trends and fashions favouring specific methodologies.

Education has produced a diversity of methodological proposals on how to teach. However, teacher-centred methodologies (mainly master classes) and student-centred methodologies (projects, centres of interest, preconceptions, globalisation, personalisation, etc.) form a fundamental polarity. On the other side, some other methods are currently in vogue in professional networks (problem-based

learning, research-based learning, evidence-based learning, thinking, competence-based learning, service learning, cooperative learning, flipped classroom, gamification, design thinking, universal learning design, etc.).

THE EMERGENCE OF SKILLS AND CRITICAL THINKING

In addition, the turn of the millennium has spawned a movement called 21st-century skills. It advocates the combined development of specific skills such as critical thinking (problem-solving, decision making, synthesis), creativity, cooperation and communication because they are considered essential to meet the personal, social and occupational needs of 21st-century citizenship.

The didactics of science assumes the previous ones and suggests other differentiated methodologies. By 1970, a procedure was already proposed: teach the four scientific disciplines (physics, chemistry, biology and geology) in an integrated way. By 1980, discovery learning advocated that students should discover scientific concepts through their autonomous work in the classroom. At that time, and based on the fundamental turn in the philosophy of science, the Science-Technology-Society (STS) movement emerged: it proposed a broader integration (science with technology plus society). It included teaching the nature of science (epistemic knowledge), particularly socio-scientific topics (a branch of STS), developing aspects of scientific thinking, argumentation, problem-solving, and projects.

Recent studies suggest a meaningful connection: learning epistemic knowledge requires students to master specific critical thinking skills. Considering that critical thinking and scientific thinking share many common skills, this conclusion is not surprising, but its implications are nuclear: the two forms of thinking complement and feed off each other, thereby enhancing their impact on learning by making thinking-based teaching a central focus for ACT.

To all this, it should be added that the so-called digital competence and media (or digital) literacy could form an integrated part of this ACT because they would naturally be included in the T for technology. In line with this idea, the Council of Europe in 2016 called for the joint development of media literacy, digital competence and critical thinking (an expression of 21st-century competencies).
In sum, critical thinking skills (creativity, argumentation, problem-solving, decision-making, and evaluation) have a broad spectrum of transversality regarding competencies, disciplines, and methodologies that make them particularly important for education and TCA.

STEM combines familiar academic concepts and integrates school, community, work and business.

THE STEAM APPROACH

In recent years, several countries have noted that higher studies in science and technology do not meet the needs of the productive system, neither in terms of numbers nor the training of graduates. Moreover, training is excessively disciplinary and poor in skills that are increasingly in demand in globalised jobs, such as transversal skills (creativity and critical thinking) and dispositions (openness, collaboration, communication and teamwork). As a countermeasure, the National Science Foundation supported some integrated, interdisciplinary, educational activities. The US administration transformed them into a policy initiative called under its acronym: STEM (science, technology, engineering, mathematics). It was planned to achieve higher educational quality, develop students' cross-cutting skills and attract more students to STEM, especially women and minorities.

As a consequence of the received economic and political support, the STEM label has become popular. It has also taken hold in many school environments, both as an educational fad and a mark of innovations aimed at a more interdisciplinary education. STEM combines familiar academic

Critical and scientific thinking share many common skills, complement and feed off each other, thereby enhancing their impact on learning.

concepts (the integration of STS) and, in addition, integrates school, community, work and business so that STEM learning benefits from this global integration. However, there is also no shortage of critical voices that, from a conceptual perspective, consider that STEM does not provide original specific content.

In addition, some educational institutions have generated initiatives to broaden the interdisciplinary scope of STEM, incorporating new areas into the acronym. Thus, the US National Academies of Sciences, Engineering, and Medicine have included the *M* for medicine, and, for years now, their publications have referred to STEMM. But the most striking addition is the humanities, adding *A* for arts (music, design, literature and fine arts) to produce the expanded acronym STEAMM. The *A* in STEAMM prompting emphasis on creativity and innovation, problem -or project-oriented: a real-world view of education in all disciplines that develops curiosity (asking questions), communication (creating answers, designing solutions) and the use of design thinking and artistic skills, while helping to bridge the long-standing gap between science and humanities. A recent study of academies provides an optimistic vision for developing STEAMM and conceptualises progressive discipline integration as shallow (multidisciplinary), medium (interdisciplinary) or deep (transdisciplinary).

IN CONCLUSION

The market's soup of educational methodologies should not prevent us from clearly seeing the educational forest. Critical thinking skills (cognitive dimension), complemented by proactive dispositions and attitudes towards all educational elements (affective dimension), and incredibly cooperative and teamwork, are indeed transversal competencies for any learning, competencies or educational objectives. In all subjects and methodologies, thinking skills must act as interdisciplinary vectors (analogous to STEAMM or STS) towards quality education and direct into deep learning, making both learning and disciplinary competencies (ACT and others) meaningful to achieve their transfer to personal, social and working life.

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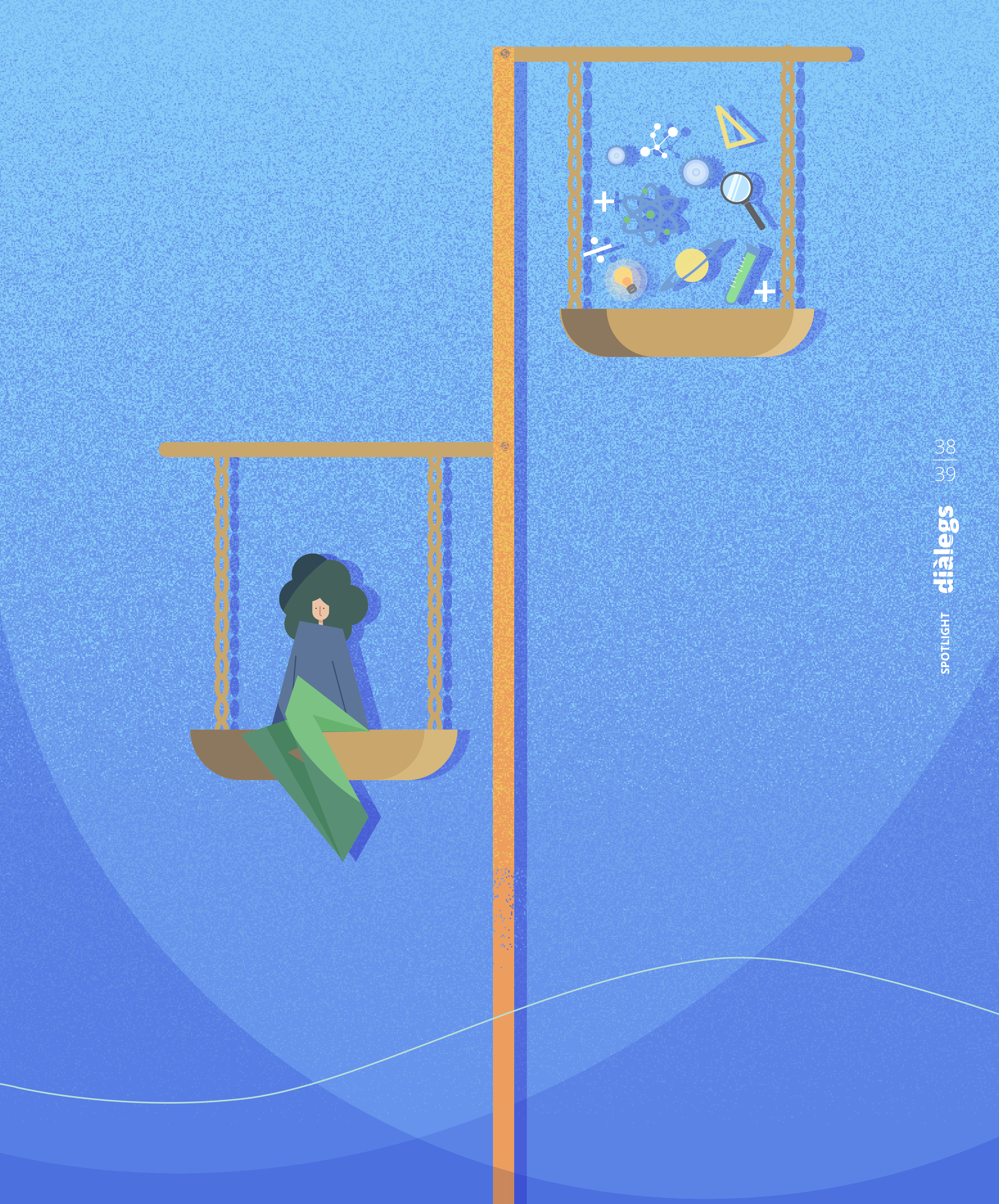


by Ester Morros

Present and future of academic guidance

Techno-science can also be of great help in discovering scientific vocations.

I am proud to share with you that I am part of that group of people who decided years ago to change the world of counselling, to propose an alternative. We are not only innovative, but also disruptive.

During this journey, professionals, researchers, technological research groups from universities and companies have participated, which to a greater or lesser extent have made it possible to find a solution today to a common problem: that of 92% of students not knowing what to choose when faced with the decision of *what to continue studying*.

It is a problem that has governments in all countries very concerned. A high percentage of those who start university studies in Spain do not complete them[1]. Knowing that around 125,000 students a year drop out, the annual losses derived from this failure are estimated at 974 million euros. This is only the economic cost, which must be added the higher cost: personal failure. This is the one we are most concerned about.

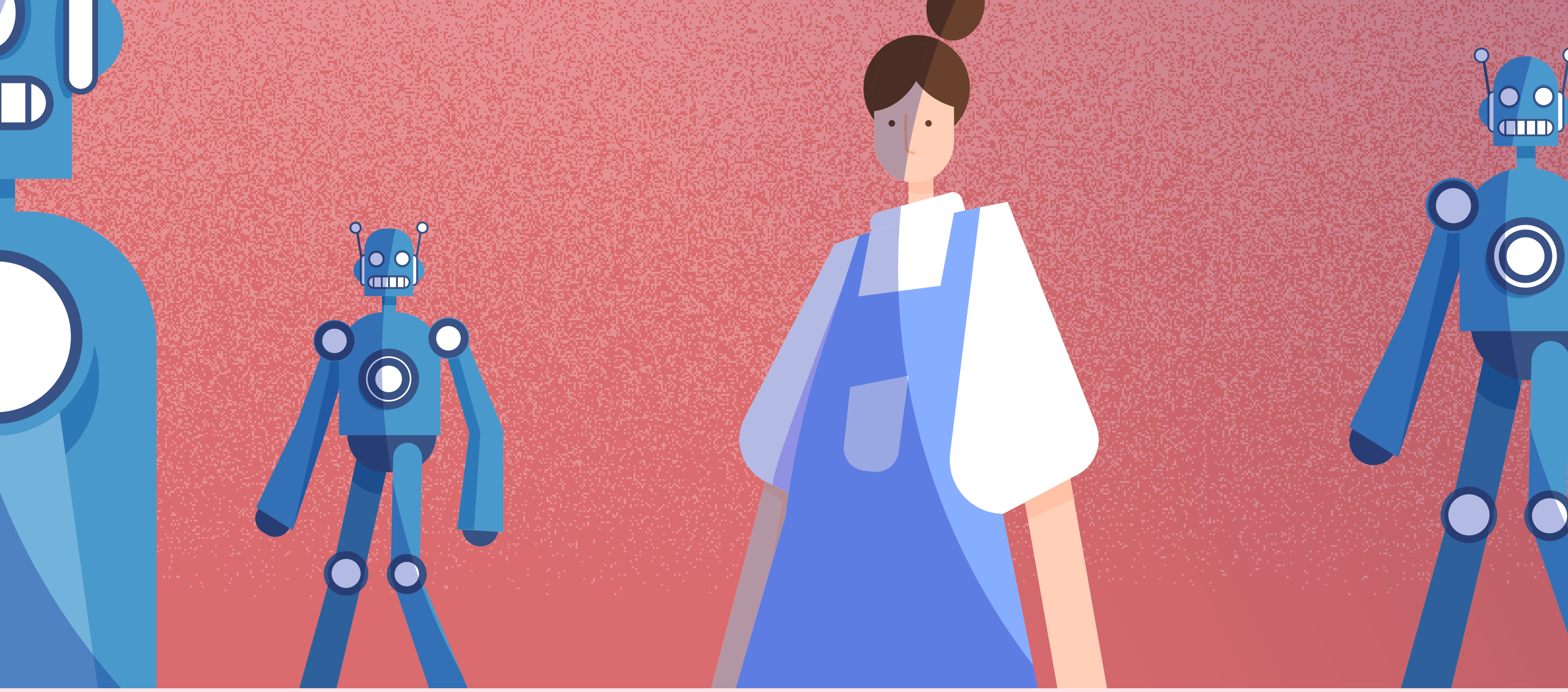
Technologies are here to stay and have a cross-cutting impact on all disciplines, including guidance. Applying technology makes business sense by standardising quality, and increasing the speed of processes, reducing costs and increasing business margins. Just look at where in the profit and loss account the personnel item goes (costs) and where the acquisition of technology goes (assets).

Technology will centralise knowledge in computers so that having thais knowledge will no longer be a differential. Hence the importance of creativity, something that today, computers cannot do on their own. A computer can perform a function very quickly, but its limitation is that it can only do one task at a time. However, under development, quantum computing will be able to do up to eight operations at a time[2].

Reading the above, it was more than twelve years ago that we decided to apply technology in the world of academic counselling, although it is true that we were treated as *Martians* at the time.

ORIENTATION

Of the seven definitions given in the RAE, perhaps the most appropriate for academic guidance is *to direct or direct someone or something towards a specific goal*.



A high percentage of those who start university studies in Spain do not complete them.

Contrary to what has always been thought, academic guidance is the help in making decisions in each of the educational and training stages, not only choosing the baccalaureate or the training cycle.

Therefore, we can no longer guide our children towards their professional future through a test alone. It is an important enough decision to devote all the love in the world to it.

Guidance has 4 key points:

1. Identify the career objective in order to design the academic pathway then, taking into account strategies based on the following differentials.
2. Identify the student's talents and strengths to determine his/her profile and best professional fit.
3. To associate future knowledge and training with their professional profile.
4. Involve parents as well as pupils in decision-making.

PROFESSIONAL CAREER

A person's professional career does not begin when he or she enters the professional field, but when they choose their studies at the end of ESO. Therefore, the choice of studies that he/she will take will largely determine his/her future profession. The very definition of orientation says it, ...*towards a certain end*. The end is the profession; the studies are the way to access it.

According to the latest report *Labour market insertion of university graduates*[3], almost 30% of the graduates who completed their studies were unemployed four years after graduation: 53% did not find a job one year after graduating, 40.4% two years later and 32.2% three years later still could not find a job. Higher education is no guarantee of finding a job.

The Gallup consultancy, a global benchmark, conducts an annual global review of the state of the workplace[4] that measures employee engagement with the company through surveys in 142 countries and 25 million employees. In summary, it finds that 83% of professionals are unsuccessful in their work and are not engaged with their work or their company. The main reason is found at the time of recruitment. He observes a dissociation between the candidate's talent and knowledge: he or she was trained for one profession and has talent for another.

The problem arises when the person chooses his or her studies at the end of ESO when he or she should associate his or her talent with his or her future studies. But still, it is difficult to ask a person to choose their future when they are only 15 years old. For a young person, the future does not go much further than what they will do next weekend. That is why parents must be involved in the decision-making process because the decision to study is not just a question of the student's academic studies but

also a family's plan for a person's future: their child. The academic result of the current guidance[5] is that 33% drop out of the degree course they are starting, 66% if it is an online course, 21% change their degree course and 12% will definitely drop out of university. These data indicate that academic guidance using the lifelong test does not work.

WE APPLY SCIENCE AND TECHNOLOGY TO GUIDANCE

In order to do this guidance, it is essential to use technology. Of course, a robot or a machine should not make our decisions, but it does help us to make them. Therefore, our guidance work is carried out by a scientific-technological tool of our own design and development, which we call *ZQtech*. What *ZQtech* offers is the result of our experience of more than 35,000 guidance processes with students and families.

Step 1: Provide information to *ZQtech*

We provide the technological tool with information on the *Job Descriptions* of the different jobs where the skills and attitudes necessary to develop the job are determined. To obtain this information, we also use technology.

Technologies are here to stay and have a cross-cutting impact on all disciplines, including guidance.

Technology helps us to classify the skills that companies are looking for and establish professional patterns, which we call *professional ADN* [6]. In addition, the academic pathways needed to access these jobs are linked.

Step 2: Collect information from the learner to create their professional DNA

The information that will be collected from the student will be, on the one hand, personal characteristics and, on the other hand, academic characteristics from a natural environment, an aspect that means that our technological system does not use any test as a basis.

The information that is collected on the platform about the student is their merits; academic record that allows us to make metrics and project university entrance grades; their interests, what the student thinks they would like to do; 360º assessment to identify who the person is from all their roles; and the student's own self-assessment. Once the information is uploaded on the platform and the invitees have responded, we can hold the decision-making meeting.

Step 3: Decision-making

At Zeno Quantum we are committed to blended systems.

During the interview, the system presents us with all the collected information, and we audit it with the family. Once the informataion is confirmed, we again use technology to convert this information into an alphanumeric code

An expert guidance consultant uses ZQTech and enables him to advise the family and the student in their decision making.

that represents the student's talent: their *professional DNA*. From this point on, algorithms and artificial intelligence take over and help us to compare the student's professional DNA with the employers' professional DNA and propose six professions that fit the student's profile.

These proposals are confirmed with the student and the family and, once they have been agreed upon, the strategic academic itineraries are proposed to successfully access these professions, from the optional subjects of the baccalaureate or training cycles to the necessary cut-off marks and university degrees.
Technological support is a great ally, as it allows the creation of personal and individual reports for each student. The technology accesses many text libraries in several languages, images and infographics to build a personal report through a complex technological system. A report that is also a living document updates the information every time it is downloaded from the platform.

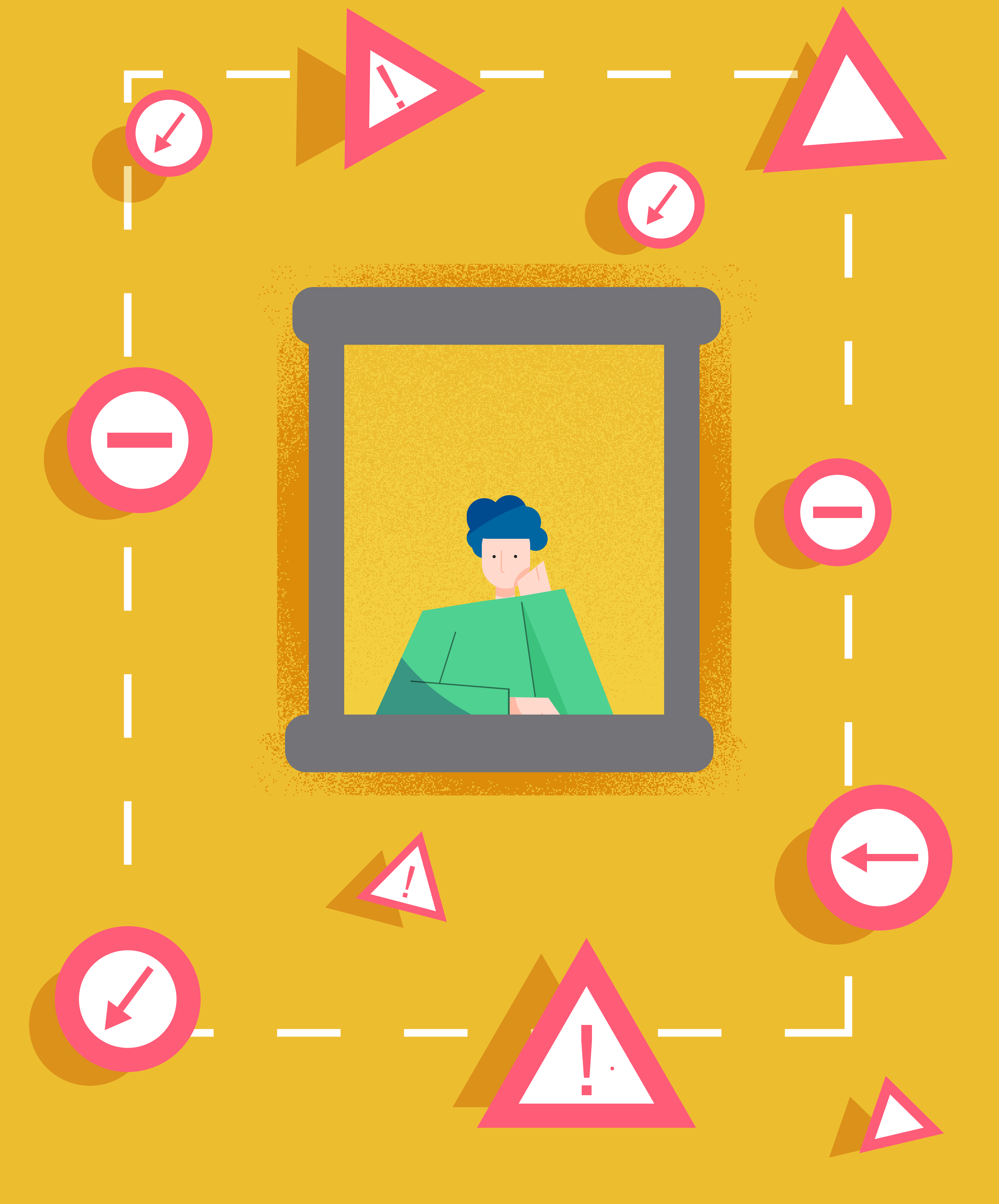
The technology also helps in terms of security, as the information in *Block Chain*, which the student will connect by entering their username and password, will create the report. This protects us against a hypothetical hacking attack on our servers.

However, guidance is a continuous process that does not end when we decide which university degree or training cycle we will do; each stage has its strategic decisions until we enter the labour market. But this is a topic for another article.

Ester Morros has a degree in Organisational Psychology from Blanquerna -Universitat Ramon Llull. Master's degree in Human Resources in organisations. Director of the scientific committee and manager of training and communication at Zeno Quantum.

Notes

[1] Estudi sobre l'abandó universitari realitzat per la Fundació BBVA del 2019.
[2] Doctora Talia Gershon (Directora d'Estratègia d'Investigació i Iniciatives de Creixement a IBM).
[3] Informe: Inserció laboral dels graduats universitaris. Curs 2013-2014 (anàlisi fins a 2018). Ministeri d'Educació, Innovació i Universitats. 2019
[4] *State of Global Workplace*. Consultoria Gallup.
[5] Segons l'estudi anual d'O-Rànquing de la Fundació BBVA.
[6] ADN professional: marca patentada des de 2016.



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

Arduino is a free platform created to bring digital technology to students of industrial design, interactive design, and art.

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?

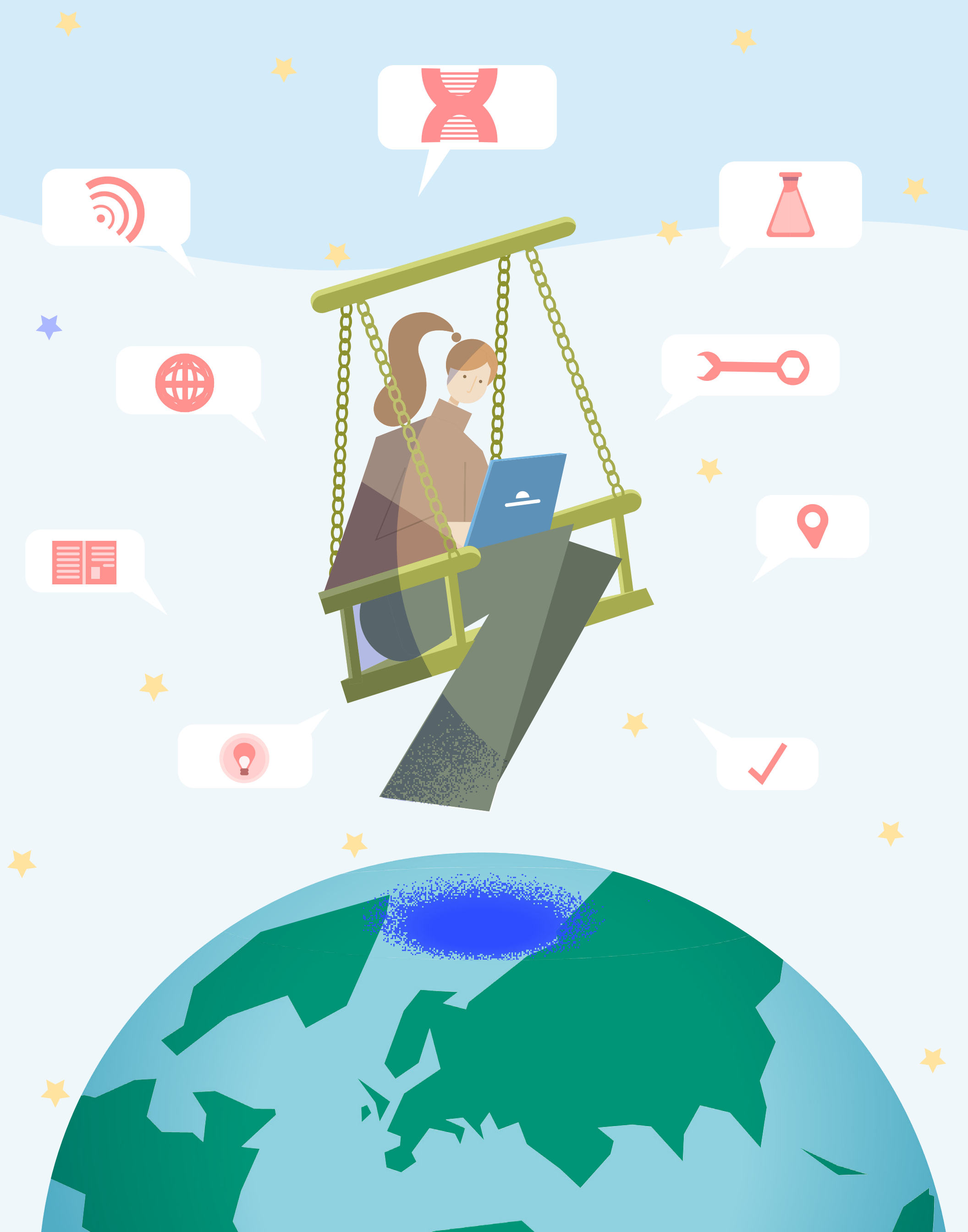
I teach at the School of Art and Communication. My students generally have no technical background, so I started this project because of the needed tool to introduce technology in the university classes.

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



Having an open tool allowed teachers 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.

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.

We came in with a concept of introducing technology when everyone talked about teaching robotics in the classroom

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?

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

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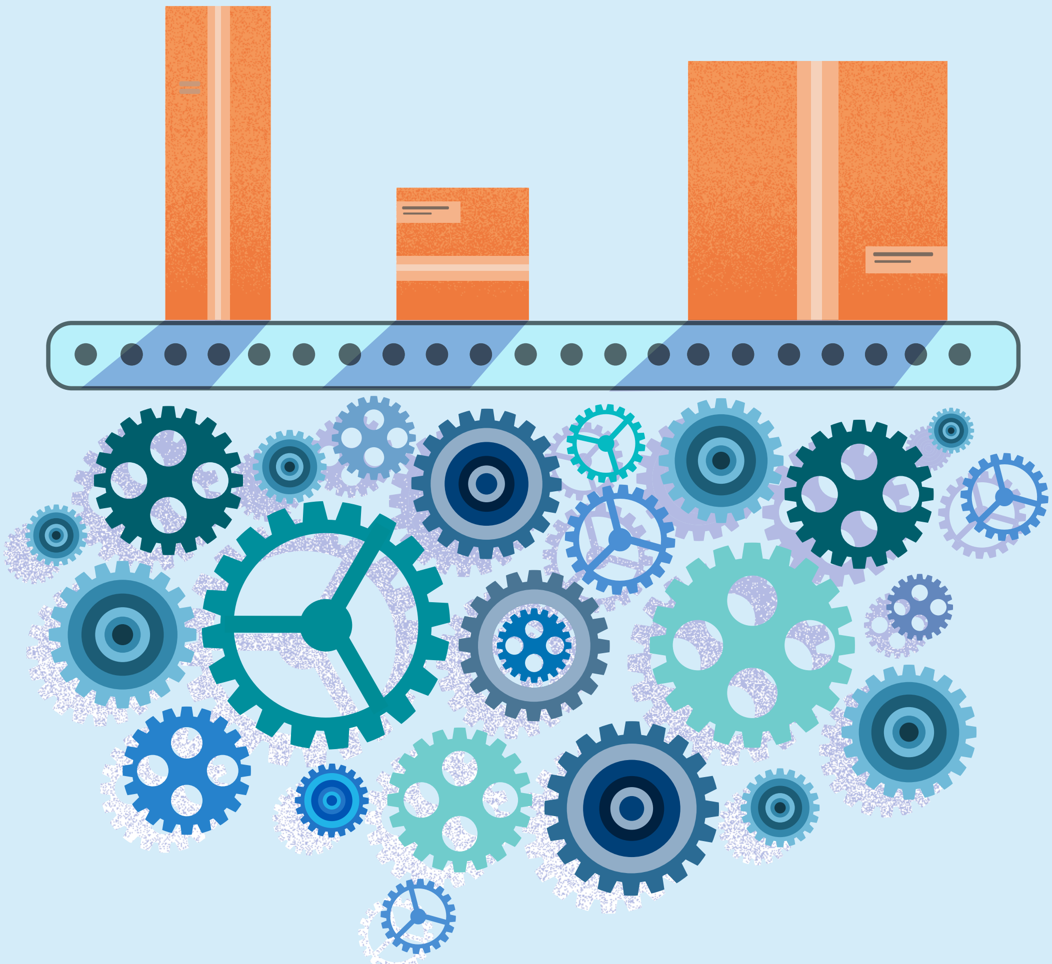


It is still unclear about the technological skills required to be a good citizen.

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.

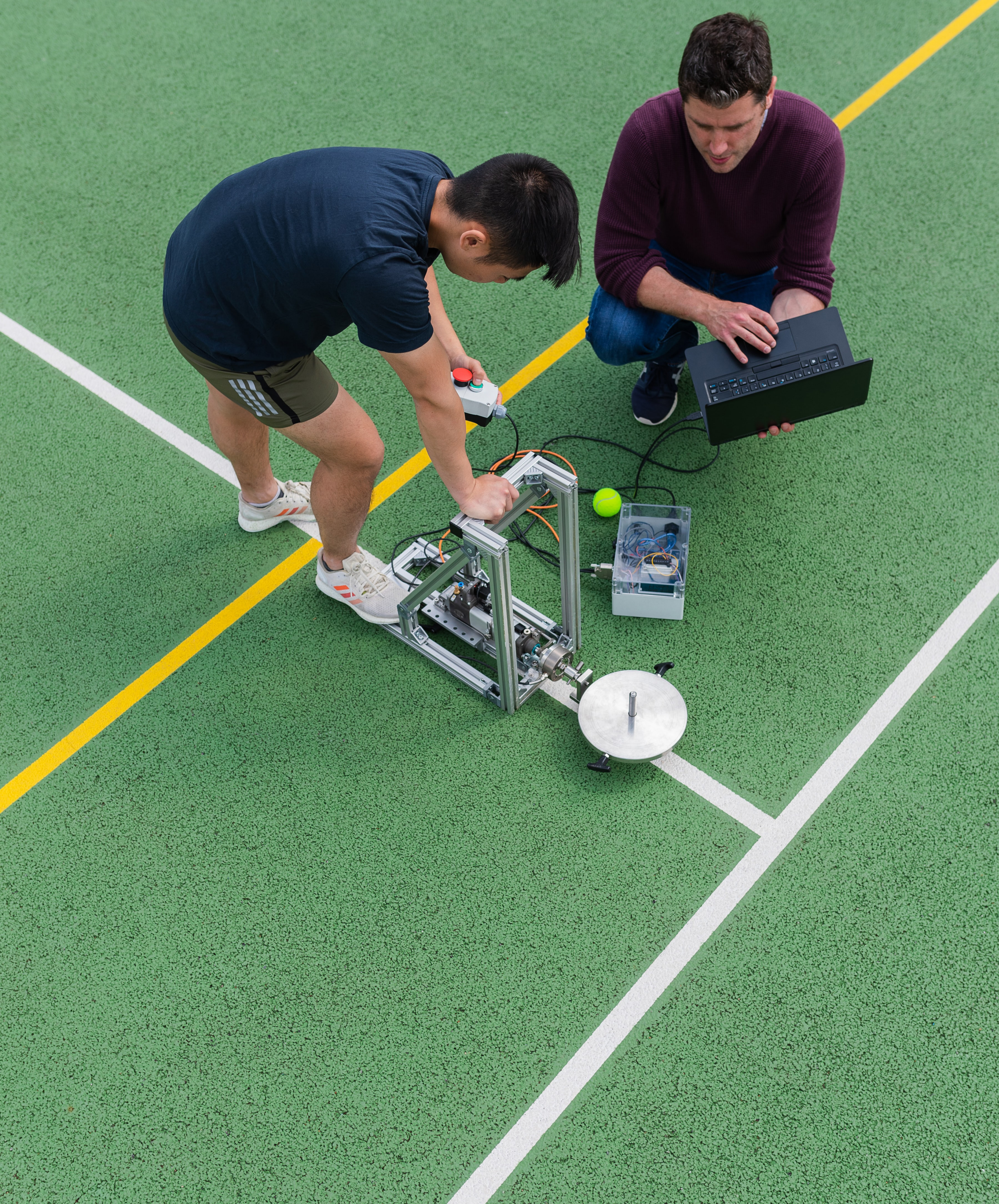
I think that improving teaching would also change things. Teaching is your primary job, but you have to research how you have to teach from the field you lead in to find the most efficient way to transmit that knowledge and make it more functional and, besides, nothing is static: everything has to be 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.

We have to rethink at a social level what kind of values we are transmitting and why the culture of effort is being erased.



by Sílvia Planella

The role of STEM education as hope for the future in a complex and uncertain world

STEM education at school to encourage technology careers


oculus

The pandemic has precipitated the advance of the technological revolution by 5 - 10 years: it is a process coming at us like a tsunami. We have only two ways of dealing with it: either turn our backs on them or join them.

It is clearly the beginning of a new productive, economic and social model in which STEM (Science, Technology, Engineering and Mathematics) play a key role.

The business network needs to adapt to change and, for this reason, professionals with STEM profiles are required more than ever.

However, this disruption comes up against a lack of STEM talent and a large part of society missing resources to adapt to this change. Therefore, it is necessary to project a community ready for a technological future and, on the other hand, to promote technical careers to guarantee people who will lead this change.

To this end, STEM education must be promoted from early childhood throughout the school stage, in a cross-cutting and integrated manner, with an applied and multidisciplinary approach. In other words, we must move from teaching STEM subjects separately to teaching them across all academic subjects. We must eliminate single-subject learning and replace it with knowledge by solving complex real-world challenges through creativity, research, innovation and, above all, the integration of various disciplines.

First of all, education professionals need to be aware of these new dynamics to implement them in the classroom. On the one hand, it will be achieved by expanding the knowledge of STEM in the faculties of education and, on the other, by training both teachers and professors in the new applied and multidisciplinary learning.

It is a good illustration of a teacher's difficulty in guiding or explaining a child or adolescent what they can do if they don't know, for instance, the branches of engineering studies and the related professions. It is also difficult for children to believe in their possibilities if the family does not support them in gaining self-confidence.

Firstly, STEM studies must be demystified from the *nerd* culture, breaking the idea that only teenagers with the best grades may think they have the potential to pursue university studies related to STEM. It is vital that, from early childhood, a vocation for these disciplines is boosted practically and experientially. Students should be approached based on their interests and abilities rather than on their curricular qualifications. Motivation and interest are most important to ensure academic success.

Actions are needed to make STEM and its professional opportunities known to the new generations and their environment, specially promoted by the Administration or by companies and entities in the sectors.

It is also essential for society to eradicate preconceived labels according to the type of training. There are no higher category studies than others, but somewhat different paths to particular professions. For instance, directing students to their vocational training or the Baccalaureate based on their academic records rather than on their interests may be a mistake: the students themselves should decide where and when to finish their training to prepare them for their entry into labour market.

On the positive side, it is worth mentioning that actions from different bodies directly impact promoting this change. Two cases are the talks given and organised by polytechnic and science universities to explain to secondary school students the existing university degrees and their access routes; also the sessions offered by professional associations to help students learn about specific professions.

An example of the latter is the *Let's talk about engineering*: free of charge lectures in Girona's secondary schools and organised by the College of Graduate Engineers and Technical Engineers of Girona, from now on, the College. Specifically, during this academic year, it has been given to thirty groups in twenty secondary schools and has reached around 700 teenagers.

The business network needs to adapt to change and, for this reason, professionals with STEM profiles are required more than ever.

Therefore, schools must include this type of action to bring STEM disciplines closer to the practical application they will have in the future in the world of work and for students to have more information to help them decide which speciality or option to choose.

But in order to awaken vocations, it is also necessary to act from Primary School. And, in this sense, the College has been committed for some time now to promoting actions that work in this direction, such as, for example, participating in the FOEG campaign. *When I grow up, I want to be like you*, where business people

STEM education must be promoted from early childhood throughout the school stage, in a cross-cutting and integrated manner, with an applied and multidisciplinary approach.

STEM must be taught throughout the school stage in a practical, attractive and multidisciplinary way, through trained professionals of both genders.

or engineering professionals visit schools to explain the profession or the preparation of an event with STEM workshops for children for Mobile Week in Girona.

The College has also promoted actions carried out by the TEG (Engineering Board of the counties of Girona) such as, for example, the virtual workshops of the *ENGINY-era* project, which were offered in July 2020, free of charge, for the sons and daughters of members, and which allowed children to enjoy doing STEM experiments at home and through gamification. These workshops were so successful that the College offered new ones for the Christmas holidays, and a new summer edition is already being planned for July this year.

And, apart from acting at the primary and secondary level, STEM learning can also be initiated at the infant stage. Many pre-school classrooms have a corner for playing shops or hairdressing, for example, but why not also a science, technology or engineering corner?

Another problem that also needs a solution is that there is often too much influence of gender stereotypes at this stage: the lack of STEM talent among women is alarming. It results in 17% of girls attending vocational training and less than 34% obtaining a university degree.

And specifically, within the STEM disciplines, there are, for example, degrees in mechanical, electrical or computer engineering, where the presence of women is scarce, less than 10%, according to data provided by the Escola Politècnica Superior de la Universitat de Girona.

Therefore, it is crucial that when STEM learning is promoted, it is done through coeducation and from the first stage of the school. Naturally, learning is done through experimentation and vocations are awakened, breaking with these conditioning factors. Some practices in this sense are, for example, the talks *Let's talk about Engineering* offered by the College through female engineers, and the presence of at least 50% of women in *ENGINY-era* activities.

To get more female STEM talent, efforts need to be made through policies that break glass ceilings in companies and promote equal opportunities.

We must go from estimating the few STEM women in vocational schools, universities or companies to making them count. We must break away from having only 7.5% of female role models in textbooks. Instead, we need living, accurate female role models teaching STEM and women leading the STEM business world. And so girls will be empowered because, from a very young age, they had confidence in their abilities and grow up believing that they are equal to boys and should not be narrowed for stereotypical reasons.

On the other hand, it is also essential to prepare children and adolescents for a professional world beyond knowledge. They need to learn to speak and write about their ideas, develop their communication and emotional skills, manage time, and work in teams to find solutions to real problems.

In conclusion, STEM must be taught throughout the school stage in a practical, attractive and multidisciplinary way, through trained professionals of both genders, to have people, men and women, capable of adapting to a technological, complex and full of uncertainties in the future world.

Sílvia Planella i Oriol is a Technical Engineer and Technical Architect and offers her professional services under the brand Enginy Consultoria. She is the founder and co-director of ENGINY-era, which is a social project that aims to bring STE(A)M disciplines to children and adolescents, breaking gender stereotypes and other discriminations. Since December 2020 she has been a member of the Governing Board of the Col-legi d'Enginyers Graduats i Enginyers Tècnics Industrials de Girona.

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European Project CHOICE www.euchoice.eu. Developed by Blue Room Innovation and the Institut de Maçanet de la Selva at State level

Managing the Future: How can STEM education help?

by Sibel Erduran and Olga Ioannidou

CONTEMPORARY PROBLEMS AND STEM

The Covid-19 pandemic has reminded us of how much uncertainty surrounds us as individuals as well as societies. Little did we know even a year ago that our world would be engulfed in such a stark new reality that we are facing in our everyday lives today, ranging from wearing of masks to closures of schools and job losses. The pandemic has been teaching us a lot of lessons about coping with an international health emergency. Important new skills are emerging. For example, the ability to cope with uncertainty has become central to our lives. Furthermore, we have become dependent on information provided by health care professionals in order to make sense of our everyday actions. Should we wear a mask? Why should we be vaccinated? How should be socialise with other people in different spaces? Such questions have many elements of STEM knowledge embedded in them. STEM stands for science, technology, engineering and mathematics, and it has become a key educational goal across the world. How can STEM literacy help equip future citizens with skills to deal with uncertainty and other unknowns that the world might be facing in years to come? What are some potential problems facing our planet and society, and how can we educate the future generations to cope with such problems?

There are indeed numerous issues that have emerged in the world landscape in recent years apart from the pandemic that present new challenges to the content of the schooling system. Rising unemployment and economic difficulties have led to movement of populations placing demands on migrants to find new ways of coping with changing life situations. The climate change emergency is already posing significant challenges to ensuring that our planet is habitable in the not so distant future. What are the skills that future generations need in order to find jobs and to deal with the new societal challenges including a new job market? STEM education has the potential to equip learners with a range of skills to make sense of and to survive in the complex problem space of the future. STEM is inherently a cross-subject approach to investigating complex scientific problems with societal impact. Covid-19 pandemic is a representative example of such issues as it raises questions about the science of viruses, the technological innovation around vaccine design, the engineering of large-scale production of vaccines, and the mathematical modelling to predict the course of the pandemic. What is more, it raises moral questions about the way in which science and technology can be used to solve contemporary problems. So, the question that arises is: How can teaching and learning STEM help students navigate current and future societal challenges?

STEM education has the potential to equip learners with a range of skills to make sense of and to survive in the complex problem space of the future.

STEM KNOWLEDGE

Understanding STEM problems requires students to be able to reason about STEM and have knowledge about how STEM works. Table 1 illustrates some aspects of knowledge and knowing in STEM and some potential questions that teachers can use in orchestrating classroom discussions and to orient the students to the importance of STEM.

THINKING AND REASONING SKILLS IN STEM

Apart from knowledge, STEM can impart students' particular *thinking* and *reasoning* skills. STEM implies skills such as creativity, problem-solving and critical thinking; skills which are all necessary to deal with ill-defined problems of the future. Furthermore, STEM knowledge is inherently inclusive of themes such as probabilistic reasoning and modelling that help us predict solutions in the future. Teaching and learning STEM subjects can also promote a so much currently needed evidence-based reasoning. All STEM fields rely on the use of evidence to sustain some claims. For example, we can justify why it's in our favour to have a vaccine against the Covid-19 virus based on the data on how it has reduced the rate of disease in people who have been vaccinated. When engineers produce prototypical models of bridges or factories, they argue for what makes the best design possible. If we are building a bridge in a gorge, we reason

ASPECT OF STEM	EXAMPLE QUESTIONS TO USE IN TEACHING
Why?	• What are the aims of STEM? • What kind of values guide STEM? • Are STEM professionals always objective? Why/why not?
How?	• What activities do STEM professionals use to collect data? • What kind of models are used in STEM? • How are models in STEM constructed from data?
What?	• What are theories, models and laws of STEM? • Are there differences between models in science and engineering? • How can we compare and contrast knowledge in different fields of STEM?

TABLE 1. Knowledge and knowing in STEM: potential questions for promoting discussions.

with evidence to confirm how the proposed construction will stay intact. Students' engagement in evidence-based reasoning may not only help with understanding how our knowledge in STEM is justified but also instill in students some trust about STEM. Across the world, we are increasingly witnessing much mistrust in science as illustrated by cases such as climate change denial, conspiracy theories about flat earth, the unsubstantiated 5G-Covid-19 which point to a whole array of misconceptions about how science works. In order to restore trust in students and more generally in the public, STEM education has to address misinformation about how science works and encourage understanding of how knowledge is validated in STEM. A coordinated approach to understanding the aims and values, processes and products of STEM is likely to help in restoring trust in STEM.

STEM, however, is not devoid of values and does not happen in a vacuum. It is situated in society and as such, the political, moral and ethical aspects of social factors can play into how STEM operates in society. For example, we have witnessed debates in some parts of the world whether or not vaccinations are against certain religious faiths and whether nor not places of worship should be open during the pandemic. In our *Oxford Argumentation in Religion and Science Project*, we have been tackling such issues through collaboration with secondary teachers[1].

Teaching and learning STEM subjects can also promote the much needed evidence-based reasoning.

STEM IN CURRICULA

How do current curricula address problems about STEM? In a recent study, we analysed science curriculum documents from the USA, Korea and Taiwan to investigate how these documents refer to the aims, values and practices of STEM[2]. The systematic study of these components provides information of how different curriculum standards compare and which particular features they emphasise. The findings illustrated that there is diversity in the way that epistemic aims, values and practices are discussed in these documents. Despite the structural differences among the documents, at least two important common themes were identified across the three countries. The first was the general underrepresentation of mathematics in the standards documents. What distinct aims mathematics has that differ from those of empirical sciences, what practices mathematicians regularly engage in and how those practices help achieve the aims of science are very rarely addressed in the analysed documents. The second theme, particularly evident in the documents from the USA and Korea, was the overemphasis of science-engineering intersection, which seemed to have resulted in science-specific aims, values and practices being hidden in the standards. In both documents, the similarities between science and engineering were represented more evidently than their differences.

STEM AND THE FUTURE

Much work thus remains to be done to bring coherence to the curriculum about STEM. Furthermore, the curriculum can no longer afford to be indifferent to the needs of the future citizens. Students who will be future citizens need the knowledge, skills, attitudes and values that will help them in their lives in the years to come. How can teaching approaches facilitate the students to acquire such outcomes now? This is a key question that we are currently exploring in our partnership in the *FEDORA project*[3] led by University of Bologna, Italy. We are exploring some solutions to a serious gap of knowledge and skills that emerges from what the traditional educational organizations are producing and what the society requires. The overarching goals of FEDORA are to produce a new future-oriented approach to science education and to foster proactive and anticipatory policy making aimed to align science education. Future-scaffolding skills include scenario thinking, systems thinking, thinking beyond the realm of possibilities, action competence, managing uncertainty and complexity. The consortium involves three research groups in Science Education (University of Bologna, University of Oxford and University of Helsinki), a research group with expertise in sociological surveys from Kaunas Technological University (KTU), a company of science communication (formicablu) and the association *Teach the Future*. At University of Oxford, we are developing guidelines to renew science education. In particular, we are targeting science education researchers, teachers and other educators in formal, non-formal and informal contexts. We will compile policy makers' recommendations for future-oriented teaching and learning in schools. Ultimately, STEM education has much potential to equip students with the knowledge, skills and values that will help them cope with the emerging challenges in the global stage.

Future-scaffolding skills include scenario thinking, systems thinking, thinking beyond the realm of possibilities, action competence, managing uncertainty and complexity.

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Notes

[1] Erduran, S., Guilfoyle, L. & Park, W. (2020). Science and Religious Education Teachers' Views of Argumentation and Its Teaching. Research in Science Education. https://doi.org/10.1007/s11165-020-09966-2
[2] Park, W., Wu, J., & Erduran, S. (2020). The nature of STEM disciplines in the science education standards documents from the United States, Korea and Taiwan: Focusing on disciplinary aims, values and practices, Science & Education. Science & Education 29(4), 899–927.
[3] https://cordis.europa.eu/project/id/872841

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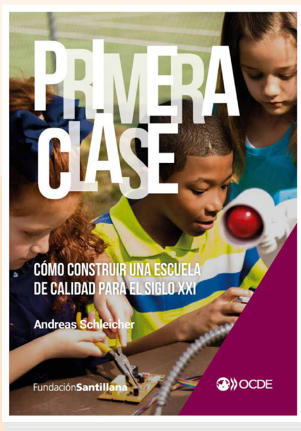
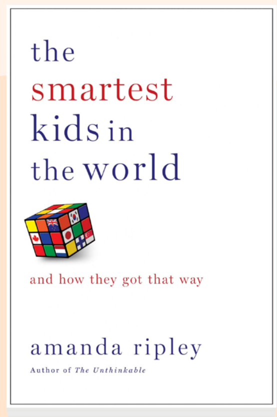


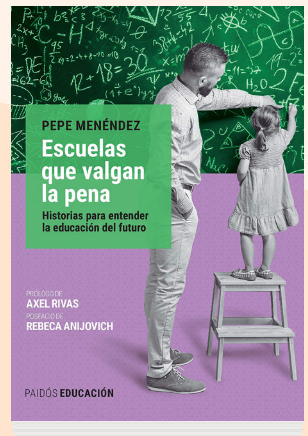
Primera clase. Cómo construir una escuela de calidad para el siglo XXI
Andreas Schleicher
Santillana, 2018

In this book, Schleicher, a physicist by profession, analyses good educational practices to understand what works in education according to its context. In the future, schools will prioritise students thinking for themselves, and working in cooperative teams, learning to be empathetic towards others. The author is an expert on international educational policy.



The Smartest Kids in the World. And How They Got That Way
Amanda Ripley
Simon & Shuster, 2014

Ripley analyses and compares Finland's educational systems, South Korea and Poland with that of the United States. She uses three students as field agents to determine the best public schools to learn how these systems educate children with great potential. His significant discovery is the passion and talent of the teachers.

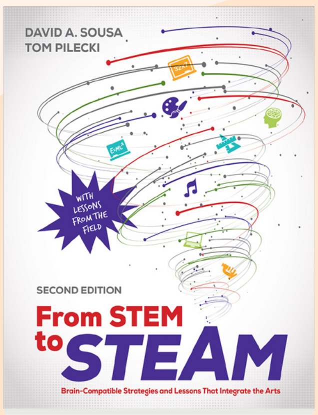


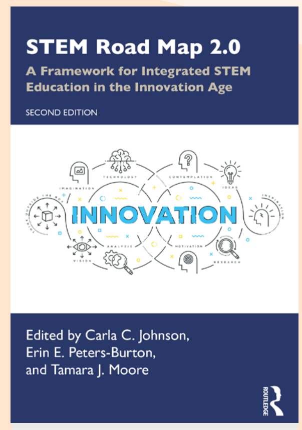
Escuelas que valgan la pena
Pepe Menéndez
Ediciones Paidós, 2020

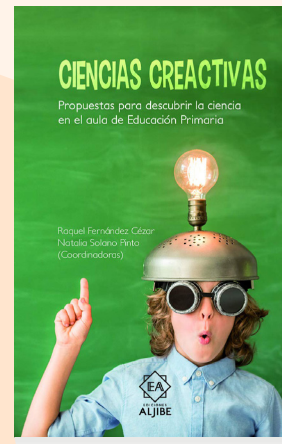
Based on brief accounts of real experiences as a teacher and director, Menéndez invites us to reflect on education, raising questions, reflections, doubts and principles, consistently placing the student at the centre of the educational process. For the author, educational transformation is based on making learning the driving force behind a more humane education in line with current competencies.

Aprendizaje basado en proyectos, trabajos prácticos y controversias
Jordi Domènech Casal
Octaedro Editorial, 2017

A book that offers 28 practical proposals for science teachers to do projects in the classroom. It is linked to a blog where all the necessary material is available. In it, we find methodological approaches on enquiry, scientific reasoning skills, project and problem-based learning, socio-scientific controversies and pseudo-science.







From STEM to STEAM: Brain-Compatible Strategies and Lessons That Integrate the Arts
David Anthony Sousa and Thomas J. Pilecki
Corwin Press, 2018, 2nd edition

Teachers and administrators in all the schools where the authors have worked have recognised that integrating the arts into STEM courses can spark their own creativity and that of their students'. The book also describes how to run a successful STEM initiative.

STEM. La enseñanza de las ciencias en la actualidad
María Napal Fraile and María Isabel Zudaire Ripa
Dextra Editorial, 2019

Across the world, and especially in the English-speaking world, initiatives are multiplying to increase children's exposure to science, technology, engineering and mathematics (STEM), thus encouraging scientific and technological vocations. Investing in STEM education has become synonymous with innovation. However, it is questionable whether the STEM education being practised responds to the challenges facing science and science education today.

STEM Road Map 2.0
Carla C. Johnson, Erin E. Peters-Burton and Tamara J. Moore
Routledge & CRC, 2021. 2nd edition

This book provides an integrated STEM curriculum that spans the entire K-12 spectrum. This edition includes an increased focus on computational thinking, mathematics, and the arts and cultural relevance and addressing student needs. Divided into three parts: conceptualising STEM, STEM curriculum maps and building capacity for STEM, each section is designed to generate a shared understanding of integrated STEM and providing curriculum maps for implementing integrated STEM at the classroom level.

Ciencias creactivas
Raquel Fernández Cézar and Natalia Solano Pinto
Ediciones Ajibe, 2019

This book shows us that there are links between creativity, science and teaching, which allow teachers to be creative in working with science through experimentation and survival and concluding with analysis and reflection shared with the students. The book contains 18 didactic guides explaining experiments on different subjects such as gravity or the magnetic field, etc. These guides propose objectives, procedures and proposals for evaluation. Examples are described using everyday materials taking advantage of everyday situations to discover, learn and enjoy science.

author

Creactive sciences

Proposals for discovering science in today's classroom

Raquel Fernández Cézar, PhD in Chemistry and Bachelor of Science in Physics, Master in Occupational Health, specialising in Industrial Hygiene, is a lecturer in the Didactics of Mathematics at the Faculty of Education in Toledo (UCLM). She has oriented her professional career to the field of multilingual science education, mainly focusing on the perception of the science of students and the general public (affective domain) in the area of STEM.

Natalia Solano Pinto, PhD in Psychology, Master in Clinical Neuropsychology and Master in the intervention of anxiety and stress, is a professor in the Area of Developmental Psychology and Education in the Faculty of Education of Toledo (UCLM). She has focused her career in health and education, researching the development of body image in the life cycle and coordinating health education programmes

by Ana Moreno

How did the idea of writing a book for primary science teachers come about? What was your purpose?
This book results from our participation in a science outreach project funded by the FECYT and the RSEQ entitled *Knowing science today opens the doors to tomorrow*. After visiting several schools to carry out experiments during four school years, between 2012 and 2016, we perceived the needs passed onto us by teachers interested in incorporating experiments into their teaching practice. They were aware of their lack of training or the lack of teaching materials that would help them connect the possible experiments with their curriculum to incorporate them as classroom material and not just to be used on special days.

Our purpose was to provide the teachers with the requested material using guides to develop the experiments in their classroom, including evaluating the knowledge acquired by the students to help them in their learning.

A large team of academics and primary school teachers took part in the book. Can you tell us how the book came about, and what was the role of each of them?
Numerous university lecturers who are both researchers and scientists have participated, but no primary school teachers are involved in elaborating the project. However, three professors from the Faculty of Education in Toledo, University of Castilla-La Mancha, were involved, including the coordinators of the project, who teach on the Primary Education Teacher Training Degree, and who focused on the formative and curricular aspects of the book.

All the teaching staff contributed to the experiments they had been carrying out in different schools. In particular, the education experts contributed to the experiments, the book's approach to the Primary Education curriculum, and the visualisation of learning and evaluation.

It consists of 18 didactic guides to carry out different experiments to enjoy science.

In the book, you propose a series of science activities with a cre-active methodology. What do you mean? Could you only just describe this methodology and explain why you consider it so appropriate?
In the first chapters, we gathered different approaches to creativity and its meaning for the primary school teacher. We also offer a methodology of discovery as an active methodology. From this combination comes the word CREACTIVE.

Much literature supports that the only way to learn is through *learning by doing*, which is also included in the European Union's Horizon Europe and previous Horizon 2020 objectives. Learning by discovery based on the scientific method seems to us to best exemplify the work of a person engaged in the scientific profession. Furthermore, some studies compare different methodologies and corroborate that the best attitude of students corresponds to the use of active methodologies, which we have verified ourselves in some research.

In the medium term, if students' attitudes towards science are more positive with this methodology, we hope that they will continue to find it attractive and choose it in their further studies at secondary school or even university.

All the activities have been implemented in the classroom; what training/information did the teachers receive before performing them? Could you tell us a test of some of the experiences? What struck you, or what do you think is relevant?

The teachers have participated as observers/mediators with their pupils in the activities we propose, as they are the ones who know them best. This is how we collaborate in the project: we bring the material and the experiments, and we work on them with the pupils. We received from them the need to have the material to do it in their classes themselves: this encouraged us to create the book.

We would highlight that as we arrive at the classrooms, the teachers or professors nearly always tell us about a student who needs special care because he or she doesn't pay attention, is disruptive, etc. But, moreover, when we finish and reflect on what has happened in class, they

Learning by discovery based on the scientific method seems to us to best exemplify the work of a person engaged in the scientific profession.

say: *Well, he or she has behaved well.*

From these experiences, we stress the need to create learning scenarios where students feel that they are the leading actors of their learning. When they are given an active and guiding role, they maintain their attention through enthusiasm and interest in learning. In addition, it is an inclusive and cooperative activity where the working groups of students carry out the experimentation at their own pace and in a collaborative way.

How do you see science learning in our country today, and what else needs to be done to make it more attractive?

Science learning is not generally based on experiments or research, which is mainly about the scientific activity. This is a fact that we regret and to which we all contribute. However, to bring about change, we must also contribute from all areas. We believe that including more micro-projects and investigations in science classes would help change the *fait accompli* view transmitted by expository teaching.

To achieve this, it would be necessary to analyse what teachers and society, in general, understand by teaching or learning. For example, if learning is conceived as an achievement when the memorised repetition of facts or even procedures is achieved, perhaps it is accomplished. However, if learning is about developing emotion, an enthusiastic and positive attitude towards science, and discovering science in the world around us, this is not reached. Therefore, the method of achieving this learning objective should be changed.

Do you think you have achieved your objectives, and when will the secondary school be ready?

The objective of elaboration has been achieved, but the social contribution of the book needs a longer time. Furthermore, it is not a best-seller, so the impact is limited; we would like it to be more significant to have a greater impact on improving science teaching.

If students' attitudes towards science are more positive with this methodology, we hope that they will continue to find it attractive and choose it in their further studies.

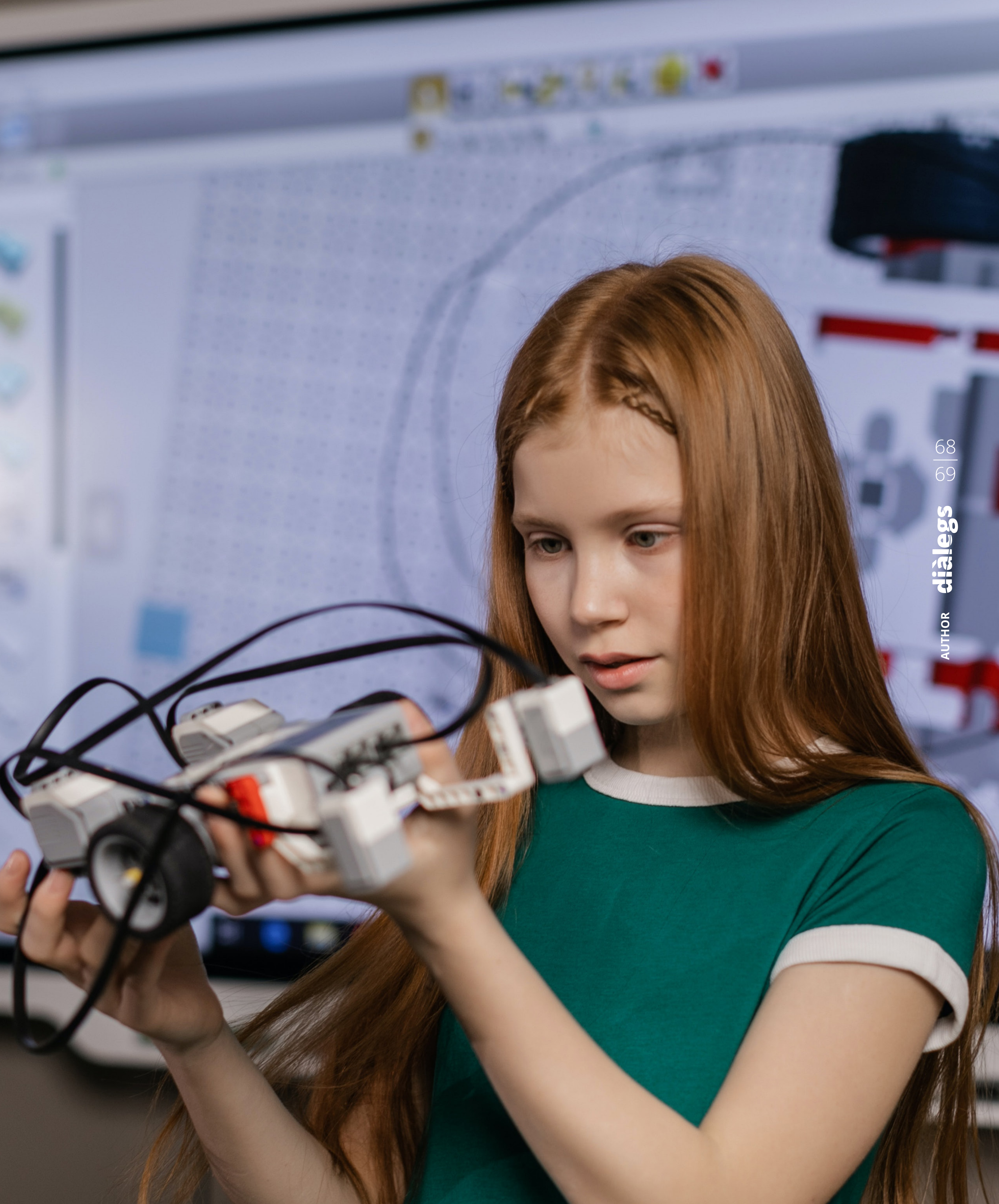
The project from which it was forged continues, so we may be encouraged to prepare the secondary material in a few years. In any case, the book contains suggestions for further development that teachers could use at this other educational stage and would be helpful to them, too.

Finally, what do you find most fascinating about the whole project and the book itself, and do you have any data on the impact it is already having on teachers and students in the classroom?

Coordination, agreeing on a model guide that would be useful for teachers, took time. However, the result compensates for all the efforts.

We have sold a few copies regarding the impact, but I cannot tell you how many. We spread it on networks from time to time, and it can be bought from Aljibe, Amazon, Casa del Libro, etc. According to the feedback we get from those who use it, it is very affordable and useful for primary school teachers. We are also grateful for the very positive assessment on *Aula Apoyo Inclusión* about the book.

As future lines of research, it will be interesting to study and compare groups to obtain empirical evidence on the consequences of using this methodology in comparison with others. More specifically, whether it improves the classroom atmosphere, group cohesion, student and teacher satisfaction, and whether it reduces anxiety about academic content, and improves scientific reasoning, creativity; and finally if it connects science with the environment around us.



Neus Sanmartí, a life devoted to science education improvement

Neus Sanmartí is Professor Emeritus of Science Didactics at the Universitat Autònoma de Barcelona. She specialises in curriculum development and assessment, the language concerning scientific learning and environmental education. She has taught at primary and secondary school levels and initial and in-service teacher training. She got the Rosa Sensat Pedagogy Award (2002) and the Cross of Saint George of the Generalitat de Catalunya (2009).

INTERVIEW WITH NEUS SANMARTÍ

Neus Sanmartí is well known for her contribution to the paradigm shift in school evaluation. Still, few know of her commitment to improving science education and her tireless dedication to achieving excellence in the teaching profession. Her dream was to achieve quality education for all, and she focused all her energy on improving public education. According to Google, a heroine is a woman illustrious for her deeds or virtues. We do not doubt that Neus is one for both, plus her great respect for plurality, awareness on teaming up and accompany professionals and institutions with diverse projects in her deeds.

by Ana Moreno

What would you tell us about the most personal Neus?

I was born in Barcelona in 1943. I was the eldest of 3 siblings. My father worked in a relative's workshop where they made cardboard boxes, and when it went bankrupt, he asked to be able to get by. I have always liked the mountains, hiking, camping - we belonged to a hiking centre, the UEC de Gràcia - and also travelling, getting to know other places and countries. I enjoy reading a lot, and from a young age, I devoured books, especially from the age of 13, when I was hooked on a book by Jules Verne *A 15-year-old captain*.

I have been fortunate to have a family that we have all enjoyed and where all three of my children - two boys and a girl - have grown up. My husband died of a heart problem eight years ago. I now have ten grandchildren, five boys and five girls, who are very diverse and who bring me into contact with today's young people in a very

experiential way. The pandemic has made it a bit difficult, but even so, we have tried to compensate for the isolation as much as possible.

How did you decide to dedicate yourself to science teaching and learning? What were your beginnings?
I have always loved science and mathematics. I still remember the pleasure I felt when my teacher helped me discover algebra and how this mathematics' area made it possible quickly to solve problems. It was probably the chemistry teacher I had in the 5th year of the baccalaureate, in 1957, who encouraged me to delve into this branch of science. And my father, who worked making cardboard boxes, encouraged me to follow this career path because he already sensed that the future packaging would require contributions from chemistry. But even while I was studying for my degree, I imagined myself as a teacher in a single-sex school in a high mountain village.

I was interested in education, which I had learned about through scouting[1], and also in nature. University (1960-1965) brought me to discover a new world of political commitment and work with very different colleagues. At that time, all of us who were studying 'science' knew each other. I experienced struggles and changes starting at the university. At the same time, I met the man who would be my partner and my children's father. Even so, I didn't see myself as a chemist in a laboratory but at a school, helping boys and girls to discover this fascinating world of science.

Although we had no training in teaching, we never stopped reading, sharing points of view, looking for solutions to the problems and difficulties that arose, innovating? And that is how we have continued.

And how did you start as a teacher?
After substituting at a school in the upper part of Barcelona for a year, I moved to an under construction secondary school in the Besós district. It was my real baptism and an apprenticeship that has undoubtedly conditioned my entire evolution. I was there by May '68, a time of struggle for a better world and creativity - imagination to the power! I learnt a lot in those years thanks to some colleagues with whom we came to understand each other and the undertaken from the 'Rosa Sensat' movement and its Summer Schools. We have just written our memories (and those of many of our students) about what we experienced there[2].

Research says that the first year in the profession marks the future of teachers, and I have no doubt that my case (and that of my young colleagues in those years) confirms this. Although we had no training in teaching, we never stopped reading, sharing points of view, looking for solutions to the problems and difficulties that arose, innovating? And that is how we have continued.

But then you went on to teach at the university. How did you get there?
The UAB was born in the 1960s, and a nucleus of people committed to a change in the school configured teaching studies. These had become university studies at that time, under the category of 'University School'. Many of us new teachers came from working groups linked to Rosa Sensat; this is why I was proposed to be part of the new project in 1965.

Even so, I thought I could not stop working at school. Plus, there was the problem the future teachers -most females- had: their professional knowledge was only discursive, and the practice centres were not always suitable. It was then when, together with other colleagues, we considered changing the model from the outset. Based on the pioneering experience promoted by Pilar Benejam, some of us teachers from the Escuela de Maestras gave classes in a primary school, which we prepared with the university students. We assisted them in the school classes, reflected on what had happened, why and what could be improved.

That was another significant experience in my professional life: the challenge in teaching, which in theory should be *exemplary* -with its good days and not so good ones- is enormous and needs to be well managed, especially the generated emotions.

I still remember the pleasure I felt when my teacher helped me discover algebra and how this mathematics' area made it possible quickly to solve problems.

Later, from the collaboration with the UAB ICE of the onwards, I also taught within the CAP (Pedagogic Aptitude Certificate) and coordinated the first studies of the 'Secondary Education Master', launched on a practical level in the 1990s.

Teacher Training Schools developed their university status in 1985. Then, professors were required a doctoral thesis, so I had to do it at King's College London, an adventure with my poor English. And since then, I have not stopped combining research, university teaching and contact with the 'real' school through in-service training and consultancy. I was a member of the first team in the Education Department: it promoted innovations in lifelong learning (FOPI, Institutional Permanent Formation, for example) and the coordination between the different Teacher

Training Colleges in the Catalan universities.

I wrote a book on science education, compiling my experiences[3], And although I am retired, I am still active at the university as an 'honorary' lecturer. I am also involved in our research group "LIEC" -Language and Science Education-: in recent years, we have been working on developing critical thinking and argumentation and, more generally, on classroom work concerning scientific controversies. That is why I was interested in collaborating with the job done by a Delphi study: experts from all over the world participated. Its results are gathered in the report *Critical thinking and creativity. Two key learnings for the knowledge society in the era of innovation*, which can be downloaded from the Impuls website[4].

How did you become interested in exploring how to transform evaluation practices?

In 1988 the science and mathematics teachers in two municipal high schools in Barcelona started implementing the LOGSE. The question arose: Shouldn't we also have to review the assessment? Both Jaume Jorba, from mathematics, and I, from science, had never been interested in the subject before, and we did not know other possible ways of approaching it.

But it seemed like a good challenge, so we looked for articles and possible references. At that time, a French journal[5] had just published an article on formative assessment. It provided research results showing pupils in high schools that applied this type of assessments obtained better results in external exams than other high schools with the same characteristics.

We were very interested in the approach because it was theoretically grounded and provided evidence. So we shared our understanding of the original proposal with the teachers we were working with: we agreed to try to apply it in their classes. This was the beginning of work that went on for eight year7 and made it possible to find answers to the difficulties that arose and check the results.

What were these difficulties?

The first challenge was getting the pupils to help them effectively and efficiently because a formative assessment requires knowing how to cooperate and assess each other. A second challenge was to improve their talking about science and mathematics. We, teachers, are used to deduce what a learner means in his reasoning or explanation, but their classmates do not.

That is why we set ourselves to get them to improve their ability to write science and mathematics. This work led to a UAB project. The book that brings together the research and innovations won the Rosa Sensat Pedagogy Award[6].

After we also considered how to select the fundamental and significant contents to be promoted, for example, how to sequence the activities throughout a learning process designed to achieve them, etc. Obviously, one never finishes seeking improvements: it is a never-ending road, and there is no doubt that evaluation is the one that helps us teachers the most to rethink our profession from many angles. I have assembled good part of the experiences and lessons learned from that beginning in two books[8], which I hope have opened a way to rethink evaluation in depth.

KEY TO UNDERSTANDING AN ASSESSMENT FOR LEARNING

For more than 30 years, Neus has worked hard to change the way teachers, students and families understand evaluation. She has undoubtedly succeeded in many cases; at the very least, she has provoked a difficult to stop wave for change.

Some of her key ideas for understanding this change can be found in her latest book *Avaluar y aprendre un únic procés*, from which we have picked a small selection to start with:

Without an assessment that helps recognise difficulties and find ways to overcome them, there is no learning. The challenge is for them to learn to self-regulate. Learning to learn is learned by learning significant knowledge -related to the various fields of knowledge generated throughout the history of humanity- and relevant in the personal and social sphere -helpful in acting responsibly. Promoting students' self-assessment is, therefore, to build essential knowledge in a meaningful way that will enable them to continue learning throughout their lives and in different spaces at school.

Assessing, learning and teaching are closely interrelated, inseparable and completely merged in the educational endeavour.

Evaluation needs to be rethought. The challenge is to

Learning to learn is learned by learning significant knowledge -related to the various fields of knowledge generated throughout the history of humanity- and relevant in the personal and social sphere -helpful in acting responsibly.

Reorienting the meaning and practice of assessment makes good learning possible for any learner. Still, its application has not yet become widespread in classrooms.

discuss the concept in-depth, knowing that what is meant by evaluation can change over time. Changing evaluation implies a profound change in terms of ideas, practices and deep-rooted emotions. Four of these significant changes are:

- Assessment that serves learning must be rewarding
- Learning requires evaluation
- The learner has to be the protagonist of the assessment
- Evaluation of results makes sense if learning has taken place

Why is it so difficult to change the evaluation? There is considerable evidence that reorienting the meaning and practice of assessment makes good learning possible for any learner. Still, its application has not yet become widespread in classrooms. One reason for this is that there is a need for an ideological debate about the purpose of education. Do we assess competitiveness to rank students or in terms of equity to promote learning for all without giving up?

A teaching team needs to consider and fix some of the following topics:

- Purpose. To improve every pupils' learning, consider their diversity and following equity criteria, or only in terms of grading pupils to classify them.
- What is assessed. Define the learning objectives as much in applying academic knowledge as in the more transversal competencies, cooperating, thinking, or managing emotions.
- Assessment criteria. What the learner would have to do to progress. They cannot be oriented towards deciding a qualification.
- Who evaluates. Mainly the learner him/herself, with the help of peers, teachers or family members.
- When to assess. From the beginning of any learning process. How the difficulties detected in each activity will be managed. At the end check what progress has been made.
- The tools and strategies. To collect data, analyse it and make decisions. rewarding and valuable for moving forward.
- How communication is articulated. Between learners, teachers and families by managing interrelationships and emotions well throughout the process.

After reaching agreements, it takes time and patience: success does not happen overnight. Whether the change is achieved or not depends on the teacher's art, science, technology (tools, techniques and strategies) to a large extent, and also on his or her ideology and values.

Notes

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Dear Neus, thank you for always pursuing your dreams, for your openness, enthusiasm and generosity.

opinion

The role of STEM in education

Students' perception that STEM areas are more complicated than other areas needs to be reversed.

by Pepe Menéndez

BACKGROUND AND CURRENT PERCEPTION OF STEM

Seymour Papert (1928-2016) is the mathematician considered the promoter of a playful methodology for learning programming, primarily aimed at children and young people, and felt a precursor of the STEM (Science, Technology, Engineering and Mathematics) initiative. Papert was a strong advocate of learning through artificial intelligence to develop children's thinking. For this reason, from the 1980s onwards, he promoted numerous initiatives using LOGO language, of which he was the creator.

We mustn't lose sight of the basis of Papert's reasoning, based on the link between play, technological gears and the development of the brain in early stages.

STEM aims to stimulate interest in knowledge areas traditionally seen as complex and unattractive for students, for girls in particular. The acronym itself evolved in several variants: the most widely accepted is the one that adds the A for Arts and it is recognised as STEAM, or the acceptance of ST2REAM (T2 for teaching or thematic instruction, and R for reading).

According to UPC data, only 29% of new enrolments were girls. Two more facts should be taken into account: they have increased by 5% in five years, and the Polytechnic University concentrates around 80% of the studies related to STEAM subjects. The Department of Education, in its publication of the STEMcat Plan in 2017, pointed out, among other reasons for promoting it, the gender stereotypes in society, and cited a study by Everis in which it states that only 26% of girls opt for the STEM-specific bachelor's degree compared to 40% of boys. This situation is even worse if we look at the family's socio-cultural level, which shows that only 24% of those with a low level of education choose them, compared to 44% of those with a high education level.

The contrast between the usual way of starting an argument in the field of science by asking questions, and the way schools approach their knowledge.

The difficulties of teaching mathematics and science at school are a classic debate in many countries of western culture, in the broadest sense, which contrasts with the great acceptance and apparent ease of teaching in Asian countries such as India, China and Singapore.

At the root of all initiatives linked to STEM -or any of its variants- is the evidence that students themselves have a poor perception of their opportunities and genuine ability to learn in these areas of knowledge. And this insecurity

is even more common in the case of girls than in the case of boys. Melina Furman, an Argentinean teacher who is well known for her work in science education, has told me more than once her surprise by the contrast between the usual way of starting an argument in the field of science by asking questions, and the way schools approach their knowledge, in which the initial questions are often absent.

ASKING GOOD QUESTIONS

Asking oneself the why of things, their origin, meaning, evolution, learning by making mistakes and experimenting are habitual scientific thinking attitudes. The truth is what it is until proven otherwise. It seems to be radically opposed to learning based on procedures without alternatives and which have to lead to a single result.

It is important to note that the very evolution of the drive for STEM (or STEAM) has been linked to methodologies that start challenging questions: they require inquiry, experimentation and selection, are based on teamwork, oriented towards the creation of an actual product that promotes learning without fear of error; and that focuses on relevant issues. They have prioritised using technologies for 3D manufacturing, *Fablabs, maker*

Providing additional ways for children and young people to connect their learning areas could lead to better results.

spaces, the use of LEGO-LOGO and other artificial intelligence technologies. This is a kind of synthesis between the conviction to disseminate scientific and technological thinking and adopting methodologies that many innovative schools are also carrying out in other curriculum subjects.

STEM AND THE LABOUR MARKET

We have often seen the importance of STEM studies underlined by European labour market forecasts, showing a need for seven million skilled jobs in these disciplines by 2025 (Encouraging STEM Studies for the Labour Market). From my point of view, focusing on the future of work to try to convince young people to take these studies is not a very wise strategy: if anything characterises young people's vision of the future of work, it is the lack of a link between their training and the behaviour of the labour market. The figures are stark: 18% school failure rate, endemic unemployment and job insecurity. On the other hand, providing additional ways for children and young people to connect their learning areas could lead to better results. If, as Cristòbal Cobo considers, the programming language is approaching the concept of basic literacy, we need to look at other learning strategies that reach all pupils.

In this sense, there are some proposals for interdisciplinary knowledge, apparently very far apart, to bring STEM closer to humanities (literature, history, philosophy...), also at low moments, and which are generally chosen for their apparent ease.

The key question we have to answer is what we want young people to know when they finish school and what we want them to have experienced, bearing in mind that we are already entirely in a world in which we will be lifelong learners.

Pepe Menéndez Cabrera is an international advisor on processes of deep transformation in education. He has a degree in Journalism. He has led several change processes in educational institutions. Communicator and specialist in leadership, educational innovation and change management.

STEM education and critical thinking training

Science teaching, in its different approaches, must be based on the socio-scientific context and the interests of the students.

by Óscar Eugenio Tamayo

The qualities that determine good teaching and learning processes are many, very diverse and of different nature. Of them all, we are now interested in referring to those directly linked to the relationship between education and context. *Good teaching* is characterised, among other factors, by being contextualised and responding to the students' interests, aspects that must be taken into account by teachers. To understand these multiple interactions, three approaches or movements in science education have gained interest in the last three decades: Science, Technology, Society and Environment (CTSA); Science, Technology, Engineering and Mathematics (STEM), and the latter plus the inclusion of the arts (A) and design as a complementary field to the above (STEAM). (Dori et al., 2018; Tamayo, 2021).

Without going into fine distinctions between these three perspectives, we can point out that they promote, among other things, the incorporation of scientific, social, human, economic, political, ethical and artistic aspects in teaching processes. Furthermore, these perspectives emerge as a rejection of the exclusively centred teaching on the scientific rationality of the different disciplinary fields. In this sense, the teaching processes that are gaining interest are those based on recognising students' interests and the socio-scientific problems inherent to the educational contexts in which the school's training activities are carried out.

THE IMPORTANCE OF CONTEXTS IN EDUCATION

Teaching science from these perspectives requires teachers to transpose or adapt these socio-scientific issues to the classroom. This process requires, in the first instance, a precise knowledge of teaching and learning contexts, as well as of the students' interests and, secondly, an adequate plan of teaching actions based on the recognition of these issues in terms of achieving both specific scientific competencies and others related to the social, human, personal and interpersonal dimensions, among others.

Teaching science from CTSA, STEM and STEAM angles strengthens the links between school science activity and the contexts in which children and young people are educated. These are perspectives that, based on contextualised teaching, contribute to a comprehensive understanding of the socio-educational contexts as well as to the scientific and technological foundations required. To this end, they guide actions in terms of scientific and technical literacy, the formation of scientific, critical and creative thinking and its integration with technology, development of communication skills related to scientific knowledge, improvement of an attitude towards science,

technology and scientific work, in the understanding of the multiple relationships between science, technology, economics, politics and the arts.

STE(A)M PERSPECTIVES AND CRITICAL THINKING

This education focused on recognising socio-scientific problems is teaching-oriented towards the achievement of critical, creative and transformative thinking, which is the school's crucial purpose. Some means to achieve this thinking in teaching are problem-solving and decision-making activities, the use of languages and argumentation, emotions-motivations and metacognition. The integration of these four dimensions acquires the conceptual and methodological particularities of different fields of knowledge: social, human science and natural sciences, arts, mathematics and technology.

Concerning the relationship between STEM-STEAM perspectives and the formation of critical thinking, we would highlight: firstly, the necessary interaction between individual and social processes, both for learning theories and concepts and the development of other dimensions of human and social development; and secondly, the recognition of the context as a starting point for warm teaching processes, in which the design of classroom interventions is based on the recognition of socio-scientific problems and considers, in turn, the transfer of learning achieved in the classroom.
Teaching in a STEM-STEAM perspective is a contextualised teaching that fosters critical and creative thinkers at its end. It requires orienting actions intellectual independence and qualification in decision-making related to the socio-scientific problems transposed for study in the classroom. It requires teachers with the knowledge and metacognitive awareness of their teaching processes. It also demands teaching action planning that articulate context and school in terms of the development of argumentative competencies and the use of technical languages in the studied disciplinary fields; in problem-solving and appropriate and pertinent decision-making; in cognitive and emotional self-regulation at the service of the students' learning processes and their performance as citizens.

Teaching science from CTSA, STEM and STEAM angles strengthens the links between school science activity and the contexts in which children and young people are educated.

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Science Technology Engineering & Mathematics (STEM): curricular entanglement and its raising challenges


by Ángel D. López and Ivonne T. Sandoval

THE STEAM APPROACH

We will talk about the STEM educational *approach* by such a name as we lack a more precise one: this proposal was born in the USA and acquired different presentations according to the added discipline or the idea *sold* to the public.

STEM is characterised by promoting an *integrated curriculum* of different scientific disciplines - biology, physics and chemistry, and mathematics - and technical ones - IT, robotics and engineering. It aims at a limited or open dissolution of their boundaries to contribute to solving everyday problems. That is to say, to make them more attractive to the minds and actions of students -from initial levels to higher education- and thus, foster educational innovation and critical thinking.

At least five different presentations have been identified, each incorporating a new discipline or a particular focus: STEM has an *i* added for *imagination* and becomes iSTEM; in the case of STEAM , *art* is added; for ST®EAM robotics is included. The last acronym is the most difficult to decipher, as it changes the symbol - R enclosed in a circle - which stands for robotics and adds an (S) for sustainability. And so, the *supermarket trolley* called STEM is growing according to the disciplines and worldviews encountered along the way.

This educational proposal implies moving towards interdisciplinarity, multidisciplinarity, transdisciplinarity, or integration by breaking down the boundaries between the disciplines that comprise it. It is a situation in which teachers at different educational levels have not been trained for various reasons. Therefore, it constitutes an enormous challenge added to the ones imposed by implementing this educational approach in classroom practice. Moreover, this academic perspective is born of economic and political interests that try to maintain financial leadership and technological innovation through education.

CHANGING WHAT WE DO, A COMPLEX SITUATION TO RESOLVE

Nowadays, technological development, historical, social and cultural dynamics, as well as the production of knowledge itself, demand changes in educational systems. There is a need to move from the individual to the collective. Some have made curricular adaptations to respond to these needs. But still, some teaching traditions are firmly anchored in lecture and rote learning, in addition to inflexible teacher training and school management, which add complexity to their implementation. Changing the "how, what and what for we teach" requires dialogue and articulation between different educational actors, an issue that remains unresolved.

Aquesta proposta educativa implica transitar a alguna forma d'interdisciplinarietat, multidisciplinarietat, transdisciplinarietat o integració.

A curricular challenge is articulating, within each discipline, different concepts, strategies, and ways of learning, harmoniously and profoundly by grade and educational level.

As previously noted, this initiative to generate classroom dynamics that blend knowledge from different disciplines is not new. Attempts have been made to put this integration into action as many teaching professionals do in their work.

In the STEM approach, research results are contrasting. On the one hand, some positions show limitations in conceptualising STEM, implementing it in classrooms, and training teachers to balance the representation of the four disciplinary areas involved. Greater emphasis on science and less on mathematics, for example, has been documented. But, on the other hand, other reports have identified its relevance for building connections between concepts from different disciplines and contributing to solving complex problems.

These contrasting research results are perhaps a call to reflect on what is not working and to discuss and agree on new educational research agendas that respond to current needs, leading to a reconceptualization of STEM.

CHALLANGE FOR EDUCATIONAL RESEARCH

One issue pointed out in the specialised literature is the lack of empirical and sufficiently broad research on implementing this approach in its different interpretations – either interdisciplinary, transdisciplinary, multidisciplinary or integrated. Against this background, there is an opportunity for the community to research such interpretations, documenting experiences in classrooms and teacher training, with methodological rigour and in different educational realities. And to seek a characterisation, based on a theoretical conceptualisation, of proposals for curriculum design and development that integrate various domains of knowledge in a balanced way, accompanied by modifications to teacher training - initial, in-service and professional development-.

CHALLANGE FOR CURRICULUM DEVELOPMENT

A curricular challenge is articulating, within each discipline, different concepts, strategies, and ways of learning, harmoniously and profoundly by grade and educational level. With the STEM approach, the challenge is how to develop a conceptual understanding - basic knowledge - in each discipline; which areas are to be integrated as interdisciplinary processes and how to develop supposedly generic skills such as critical thinking; but also how to articulate four disciplines, in which whatever is learned in each STEM area is distributed in a balanced way, without one of them being more visible than the others, reflecting multidisciplinarity or interdisciplinarity. That is, reflecting deep connections between disciplines when solving problems or developing projects.

CHALLANGE FOR TEACHER TRAINING

STEM involves the teacher, on the one hand, having general knowledge about each of these areas and, on the other hand, making connections between them. Therefore, it is crucial for teachers in initial or in-service training to experience individually and in groups how teaching content, skills, and ways of thinking from different disciplines interact, how they can support each other, and substantively complement each other.

What stimulating challenges we have to face.

STEM involves the teacher having general knowledge about each of these areas and making connections between them.

Recommended reading

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