Teaching, Communication, and Dissemination for Society

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Abstract The dissemination of scientific culture in society is assuming new forms. On the one hand, digitalization and the affirmation of social networks imply the implementation of a new communication strategy to fulfill people's need of knowledge. On the other hand, science is not free of interconnections and is moving toward an interdisciplinary approach, mixing disciplines and languages. As a result, the language of science is changing and so is the language of science communication. What are the new challenges of science communication? How can science be communicated and taught in the new millennium to promote the learning of science in society and to strengthen cultural awareness of scientific issues? In this chapter, the authors discuss the features and the evolution of teaching, communication, and dissemination of science, offering new (technical and digital) strategies to build an effective way to use the potentiality of natural language to spread and teach science in our society. Based on the scientific literature, the arguments are shown in a form of dialogue, inspired by the famous Galilei's "Dialogue Concerning the Two Chief World Systems".

Keywords Teaching · Science communication · Dissemination · Physics education · Outreach · Scientific culture · Learning of science · Language · Scientific awareness · Scientific literacy

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1 Introduction

The history of Western culture has been an evolution toward the conquest of scientific knowledge at least since the birth of philosophy. In this process, the explanations and reasoning progressively had been moving back from the sphere of religion, myth, and magic to become more and more founded in a scientific method. Yet the two spheres continue to coexist, and we still find processes connected to both spheres in our societies, media, and educational institutions. We can think, for example, of the hybrid arguments about issues that are fundamental to our existence: vaccines, nutrition, even meteorology. Many people are willing to hold on them beliefs that are not based on scientific knowledge, but on acts of faith (not necessarily toward a deity, but toward a leader, an opinion leader, or an influencer). One only must review the abundant literature on fake news to realize the extent of the problem. To fight against this problem, we are assisting at the advent of schools, media (especially newspapers, but also many social profiles) and professionals specifically concerned with popularizing science working hard to counteract information that is false, unfounded, or based on approaches outside science.

For several decades now, scientific research has changed its face in the relationship with society. Today science is no longer a world unto itself, where researchers live in their ivory towers disconnected from the real world, but is a reality now closely connected to all major players in civil society, from politics to industry and to the communication world. People ask science to satisfy their needs, and, in this process, science is perceived as synonymous with technology (Gouthier and Ioli 2016). The link between the researchers and the public, the recipient of the many initiatives for the dissemination of scientific research, is particularly delicate and important. Here, too, conditions are very different from the past: if once the communication approach was based mainly on the so-called “deficit model” (see Simis et al. 2016 and refs therein), which aimed at a simple transfer of information from experts to the public (considered a completely passive subject), today the keyword in science communication is “interactivity” (Trench 2008). As a result of the explosion of social networks and the quick evolution of the media, today the public can dialogue and directly interact with experts, thus finally becoming an active part in the process of dissemination of the research results and their implications on society. This interaction is not always easy, peaceful, and effective, as the communication related to the recent COVID-19 pandemic also demonstrates. However, it is impossible to turn back: the relationship between researchers and non-expert citizens is traveling in a direction where dialogue and direct interaction will be increasingly dominant. Partly because of this, it is now almost a requirement for scientists to complement their research work with a serious and effective commitment to public science communication. An effort that must aim not only to disseminate the results of one’s research but also to make people understand more generally the mechanisms of research and the scientific method.

A key point in generating a virtuous and profitable relationship between scientists and citizens is to analyze which way the two perceive science. It is generally diffused the idea that only the science that can make use of mathematics is the real science. This is a common belief today as it was in the past, especially in academia. Aristotle had already realized this when formulating the principles of logic, dialectics, and rhetoric (Piazza 2004). Human sciences are usually not even considered scientific: either they have hard-won hybrid status, such as sociology, which distinguishes between quantitative and qualitative methods (Corbetta 2014), or they are considered just disciplines that tend toward science, such as psychology (Engel 2000).

If, on the one hand, the use of mathematics as the language of science dates back to the works of Galilei and Newton, on the other hand, many studies have underlined the role of imagination in building scientific knowledge. The use of metaphors to imagine the world of the invisible and, therefore, to build an (even detailed) description of phenomena plays a central role in science. Einstein himself, in a letter to Jacques Hadamard, mentioned the importance of visualizing the world through images: "The words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The psychical entities which seem to serve as elements in thought are certain signs and more or less clear images which can be 'voluntarily' reproduced and combined". (Hadamard 1954). Lakoff and Núñez (2000) maintained, for example, the centrality of conceptual metaphor to a full understanding of many ideas in mathematics, as the concept of actual infinity, specifically.

Referring to physics, one of the most famous cases is how knowledge of the atomic world was conveyed through the image of the solar system (Rutherford–Bohr model, 1913). Soon, Bohr himself and other scientists realized that the mathematics used to represent the motion of the planets could not explain the motion of electrons in atomic orbits, nor the phenomenology of atoms bigger than Hydrogen (Rabatzis and Ioannidou 2015). However, the mathematics used today in Quantum Mechanics was developed based on this "false" metaphor, which nevertheless forms the basis of this branch of physics. The use of metaphors as a guide to exploring nature is still evident in other areas of physics. This is the example of Einstein's General Relativity, where new words such as "black holes," "Big Bang," or "primordial soup" have been invented to talk about the final state of matter after the explosion of a massive star, the origin of the universe or the initial state of matter and energy in the universe, respectively.

Analogies, metaphors, and other linguistic resources are quite used when scientists and professionals communicate science to people. The role of Stephen Hawking or Einstein itself in outreach through their books (Hawking 1988; Einstein and Infeld 1938) has been fundamental to bringing high-energy physics themes into society. The possibility to imagine the invisible mediating through language tricks inspired many generations of high school students, leading them to be passionate about physics and, in some cases, to work in this field. Many other examples could be given in this direction (Root-Bernstein and Root-Bernstein 1999; Postiglione and Angelis 2021).

Appropriate use of the various forms of language (mathematical and natural, formal, and informal) is important also in education, especially in didactics. The interplay between formal and non-formal language becomes evident when we pass from formal traditional teaching and learning of science (typically in schools, with final evaluation and certification) to non-formal (such as in summer school, masterclass and similar for the former, with a limited evaluation of learning) and informal environments (such as in museums, science shows, social networks and similar with no evaluation at all) (Oriji and Uzoagu 2019; Ucko 2010). In the context of informal learning of science, the experience of learning a specific subject is tacit and implicit, placed in the background of the experience of playing with and freely enjoying science (Hall 2009; Ward et al. 2013; Michelini 2005). In all these approaches, a student-centered environment for learning (Land et al. 2012), regardless of its shape and context, is needed. In this way, the language of science assumes new features, adapting and transforming according to the audience.

Simplifying the language without losing the rigor of the discipline is the most difficult challenge for every communicator, being him/her a scientist, a teacher, or a professional in communication. The more learning is devoted to non-experts, the more images should be produced to visualize and think about the phenomena, fostering the audience's motivation toward science and its creativity (Petrescu 2016; Gobet 2015). Such a process should be well defined by also communicating the limits of such analogies, thus preventing possible misunderstanding and false images of the world (see Teixid et al. 2019; Watkins 2014 and refs therein as an example). The use of a hybrid forms of languages, where science contents are communicated through visual thinking (Coll 2005), goes in the direction of using new digital environments for teaching and learning. This is the case with social networks, where new opportunities are now appearing to share science with a large audience (Otte and Rousseau 2002; Zaidieh 2012). Nowadays, offering a contemporary vision of science to high school students and teachers should be a common goal of outreach activities and informal learning of physics mediated by researchers. Indeed, science is evolving, and its forms and languages are changing. To give new instruments to learn science and physics in an enlarged context, mixing knowledge, techniques, and methods from different disciplines is becoming a priority for scientists and society (Pan et al. 2012; Pluchino et al. 2019; D'Este and Robinson-García 2023; Spelt et al. 2009; Davies and Devlin 2007).

For all these reasons, we present here an overview of the state of the art of the evolution of science teaching, dissemination, and communication for society. Inspired by the "Dialogue Concerning the Two Chief World Systems" of Galilei (1953), in the following, the authors of this chapter discuss the world and the vision of science, offering a scientific argumentation on how the language of science is changing. The discussion is divided into four sections referring to formal and non-formal languages, that is, how science is modifying its habits to find new answers to old and present questions, as well as, how the communication of science is adapting to these rapid changes. The dialogue ends with a discussion on the role of interdisciplinary in science communication and in the teaching of science at school, giving insights into recent methodologies now explored in the field of education. All along the dialogue, they offer some reflections and analysis based on the literature cited in the bibliography. MT stems for Matteo Tuveri, EG for Elisabetta Gola, and MS for Matteo Serra. The chapter ends with a summary of the contents dealt with by the authors and reflections on the future of science communication and education.

2 The World and the Vision of Science

MT: “What is science? Physics, mathematics, and chemistry are good examples of what, at least in the collective imagination, is thought to be a good representation of what science is or should be. Is it something based on the language of mathematics, something very rational, capable of offering solutions to problems, and leading our minds out of our common sense to discover what nature is made of, or something else? So it is, for scientists as well as for everyone else. But science is also perceived as capable of solving people’s problems, and it does with the help of technology. In some sense, in the common imagination, science is technology, built for satisfying everyone’s needs. For someone else science is also perceived as a difficult subject, often involved in studies about the invisible, not so urgent nor so important. So, what can we say about science?”.

EG: “The world of science is a vast and heterogeneous field, not least because we should first ask ourselves what we mean when we speak of science. Certainly, if we must consider a prototypical case, we can point to disciplines such as physics, mathematics, and chemistry, on which there are no controversial positions on their nature: they are science and they deal with scientific subjects”.

MS: “I would also add that science does not produce any irrefutable truths, but rather a set of “provisional” truths that can always be challenged by discoveries and insights: correctly explaining this and other key features of research is essential to improve the public perception of science, and scientists themselves must do this, in addition to professional popularizers and communicators”.

MT: “So, if science is not infallible, it does not produce eternal truths but rather local and temporary models of nature, corroborated by experiments and rigorous studies on specific subjects, why there is not a social agreement on that? What is missing in our society? Maybe the communication itself?”.

EG: “Indeed, the skill profile and how science is disseminated, taught, or communicated differ from discipline to discipline. “Physics is a science”: this is a statement on which everyone agrees. The existence of a clear method such as the Galilean “scientific method” based on experiments, verification or falsification of someone’s theory or hypotheses about a phenomenon ensures the status of science. On the contrary, life sciences, such as biology and even more medicine, are fields in which the actual scientific method coexists with ‘artisanal’ or ‘artistic’ acts that are an integral part of the knowledge for those who engage in these disciplines. Human sciences are usually not even considered scientific: either they have hard-won hybrid status, such as sociology, or they are considered just disciplines that tend toward science, such as psychology”.

MT: “Maybe, we should communicate not only the discipline and its results but also the world of science. Shouldn’t we?”.

MS: “Indeed, we still too often refer to the research as something impersonal, forgetting that scientific research is made by people (researchers), with all their baggage of human stories, talents, and weaknesses. The “humanization” of science in the eyes of the public can be one of the missing ingredients, a key step in fostering and improving the dialogue between the research world and citizens, helping to decrease the level of distrust in science that still exists”.

3 The Language of Science

EG: “There is a common belief now as in the past that the sciences that can make use of mathematics are the real sciences. Thinking about it, Aristotle had already realized this when formulating the principles of logic, dialectics, and rhetoric, and it emerged in all its epistemological force in the authors who explored the possibility to build a language specifically for science (a kind of meta-mathematics) and capable of maintaining the ‘truth’ in the transition from one statement to another. These languages, universal and perfect, have been sought since at least Ramon Llull in the Middle Ages, and have been explored with greater frequency and commitment in the age of the scientific revolution by Bacon, Descartes, and Leibniz”.

MT: “However, mathematics and formal descriptions alone are not sufficient to build science, nor the language of science. What is scientific progress if not a texture of past knowledge mixed with some new idea to build the new theories? There have been moments in history in which no discoveries at all were possible. Someone invoked revolutionary people to change the status quo, bringing new revolutionary ideas into the game.[1] There is also a smooth way to see it by the introduction of accumulation points of knowledge well interpreted by people who, studying the past and invoking the transversal thinking, made a synthesis of contents to build the future.[2] But knowledge passes through any form of language, to build it and to transmit it. Language, in turn, transforms over the years and, thus, passes through knowledge. Looking at scientific problems in a different way led to the emergence of new mathematics, and new terms in the natural language to refer to it. Therefore, new concepts to explain and communicate a new vision of the world manifest in time”.

EG: “If we look at the history of science, we can notice that it is imagination, in most cases, and not a formal automatism, that makes knowledge progress. We were under the illusion for a long time that language was a compositional and deductive system, and that we could almost automatically move from axioms to theorems. But today we know that our possibilities of expression are anchored and bound to the way we are structured, that is, they are ‘embodied’. That is why it is no coincidence that we

[1] See Kuhn (1962) for details.

[2] See Morganti (2016) for details.

speak of progress as something that moves forward, for example, because our motor patterns translate into symbolic and metaphorical patterns. Conceptual metaphors are central to a full understanding of many ideas in mathematics, as the concept of actual infinity".

MS: "The communication of physics, together with other scientific disciplines, is emblematic in this case, providing an interesting reference case study. Indeed, those who communicate physics and its discoveries have always had a major problem to overcome. Unlike other disciplines, often the 'objects' of physics cannot be perceived with our senses. No one has ever 'seen' with their own eyes an electron, 'touched' a gravitational wave, or 'felt' a neutrino. This is a big problem because all forms of communication play primarily on the solicitation of the audience's senses".

MT: "This is, for example, the case of Quantum Mechanics (with new terms in correspondence of a new phenomenology such as 'quantum', 'wavefunction', 'entanglement', 'wave-particle duality', ...), or even of General Relativity ('spacetime', 'warping of space and time', 'gravitational waves', 'black holes', 'primordial soup' and so on), in physics, where new terms had to be invented to understand, describe, and communicate the manifestation of nature to scientists and people, too. Quantum mechanics looks in detail at the smallest scales of the universe, whereas General Relativity looks at the largest ones. Natural language, as well as the mathematics, are involved in both cases to describe two invisible sides of the same coin. The former manifests itself with new images to represent and describe new scientific images of the world. The latter glues the experiment with logic and a rational description of phenomena, building models and falsifiable predictions of peculiar features of nature. In both cases, a language is needed, and language (natural or mathematics) and learning are deeply interconnected. They are intertwined subjects and knowledge is a result of their interplay. Isn't it?".

EG: "Yes, they are. One of the most important results of this interplay is one common expedient used by scientists to visualize the invisible: using images, more specifically, metaphors. Imagination and, metaphors, have always played a central role in science. Physics offers a good example in this direction. Let us think of the most famous images of physics, that is the atomic world as the solar system, black holes, or the primordial soup. None of them exactly represents the actual manifestation of nature in specific conditions (electrons and atoms, the gravitational collapse and the formation of a black hole, or the initial instants of the universe, respectively), but they help in imaging the invisible world. Metaphor is a cognitive process that we constantly use to try to understand the things we are exploring, to describe them, and to find explanations and laws. A theory is not formulated from scratch, but we conceive new hypotheses using something we already know, including expectations and biases. In the case of metaphors, we refer to an area of inspiration and project the structure, the relationships among the elements, onto the realm we want to know. In this process, we find confirmations and rejections, and in this process, new knowledge emerges. The sciences that can make use of mathematics are those that have come closest to the goal. However, if we look at the history of science, we can notice that it is imagination, in most cases, and not a formal automatism, that makes knowledge progress".

4 The Communication of Science

MT: "What is emerging from our discussion is that knowledge passes through languages. Science has its languages: the one based on mathematics and the one based on the natural language upon which the scientific understanding and learning of phenomena are built. The former is often thought of as exclusively for experts, due to its technicality. The latter is the most fluid one: it can easily assume the shape of a formal language when it is used in a specific and technical way (e.g., scientific English, the explanation of a mathematical demonstration, or the exact description of a phenomenon according to a general model). It is also the instrument to communicate science to non-experts, in outreach events, magazines, tv-shows, social media, newspapers, etc. In all these cases, the speaker is asked to talk simply, emptying the communication from all the technicalities and the specific formalism of the discipline. Thus, we are left with two ways to explain the concept which depends on the public to whom we are referring".

EG: "And the principles of communication are the backbone of many professionals: journalists, teachers, writers of manuals, social media managers, physicians, and even those who work as clerks in universities and public sector administration in general. However, they rarely receive specific training in scientific communication (and in some cases, e.g., teachers and clerks, in communication tout-court). But this is necessary to be able to design and implement an effective communication: it is not just a matter of translating concepts in words, knowledge and language are two sides of the same coin".

MT: "Speaking metaphorically, who will be the final user of this coin? On the one hand, we said that there are people involved in communicating science, such as journalists, teachers, or science communicators. On the other hand, the recipient of the communication, the one who will make use of all this information, is the public, made by scientists or people in general. Thus, in the process of disseminate, explaining, and telling science, the public is at the center of the communication and the language plays the role of the theater where communication is on stage. So, how to communicate science, especially to the public, to society?".

MS: "Well, we can make some specific examples of good practices of communicating science to the public. In 2016, the LIGO and Virgo collaborations first announced the discovery of gravitational waves,[3] ripples of space–time produced by violent astrophysical events, predicted by Albert Einstein's general theory of relativity. To

[3] See Abbott et al. (2016).

bring the public closer to this great achievement, during the press conference where the discovery was announced, LIGO and Virgo researchers played an audio transduction of the gravitational wave signal, which was very helpful to understand more precisely the 'shape' of the signal. In 2019, researchers from the Event Horizon Telescope collaboration instead published a 'picture' that quickly went around the world: it was the image of the shadow of the supermassive black hole at the center of the M87 galaxy.[4] It was the first time one could literally 'see' a black hole (or at least its edge): needless to say, the effect on the audience was extremely powerful. The same effect was then replicated (if not enhanced) in 2022,[5] with the publication of the first image of the black hole at the center of our galaxy, the Milky Way. In formal or non-formal communication, solicitation of the audience's senses, whether it is an image, a video, an audio track, or even an object to touch (think for example about hands-on installations in science museums) is fundamental. This could be a good practice in communicating science, especially to non-experts".

MT: "I completely agree with you. Let us imagine what happens in the case of formal communication, even from experts to experts. In this case, the communication plan is based on involving the capacity of giving a sense of reality to abstract symbols, or languages, as in the case of formal and technical scientific communication, for example, when mathematics is used. The solicitation of imagination using metaphors as well as analogy is even stronger in the case of informal learning or dissemination of scientific knowledge (outreach events) to people. Playing with objects and participating in hands-on and mind-on activities is important to help people in learning, even in informal contexts such as science shows or museums. An immersive experience which involves all the senses is more effective than others and, in some sense, is welcome when communicating science to people".

EG: "When we refer to physics as science, those who 'disseminate' are the teachers (in all schools at all levels, but especially in those schools where 'physics' is a specific subject of study) and the disseminators are necessarily experts in the subject. As soon as we move away from this territory and step in a slightly less mathematical topic, this coherence is immediately broken. To give an example, it is not only doctors who argue, speak, and give references to vaccines, therapies, and foods. And the arguments are no longer deductive demonstrations, but conclusions, inferences, and metaphors. However, these types of argumentations may or may not be considered part of a scientific method".

[4] https://eventhorizontelescope.org/press-release-april-10-2019-astronomers-capture-first-image-black-hole.

[5] https://eventhorizontelescope.org/blog/astronomers-reveal-first-image-black-hole-heart-our-galaxy.

5 Toward an Interdisciplinary Approach in Communicating Science

MT: "A conceptual change is happening in the world of science. Scientific disciplines are moving to interdisciplinarity, where new solutions to solve old and still open problems can be found. Physicists collaborate with biologists to tackle the problem of pandemics, or with pharmacologists to find new drugs against bacterial infections. They collaborate with engineers and informatics to build new super and quantum computers which are opening the doors to new technological applications. Physics has always had an interdisciplinary approach, even in the past, where it was strictly connected with philosophy. That was the time when revolutions in our understanding of nature happened, as in the case of General Relativity and, again, of Quantum Mechanics. After some years, the two disciplines took different paths, both kidnapped from their intrinsic technicalities. But, I guess, this interdisciplinarity could be restored even today. As already mentioned, the history of science taught us that from the mixing of different perspectives it emerges a new understanding of the world around us. Why do not try to combine different visions of what we know to offer a complete reading of the world of science? A similar experiment could be done starting with schools, where a universal form of learning is offered[6] in students' curricula. It could start a new education era when new methods to explain phenomena around us and new strategies to do it could emerge in school and academia. Therefore, a new language will be needed".

EG: "Which language? Language itself is changing. We were under the illusion for a long time that language was a compositional and deductive system, and that we could almost automatically move from axioms to theorems. But today we know that our possibilities of expression are anchored and bound to the way we are structured, that is, they are 'embodied'. That is why it is no coincidence that we speak of progress as something that moves forward, for example, because our motor patterns translate into symbolic and metaphorical patterns".

MS: "In this regard, the examples cited above, and the resonance these discoveries had in the media show that one can succeed in effectively communicating a major physics discovery, despite the inherent difficulties that we have mentioned above. With one crucial sticking point: it is always essential to explain to the audience how that specific representation of discovery was conceived. So, relative to the examples cited above, to say clearly that the 'sound' is not produced by the gravitational wave, but it is an audio transduction of the signal, or that the picture taken with the EHT is not exactly a picture of the black hole, but a reconstruction of the image of its shadow".

[6] Such kind of experiments have been made during the "Gravitas" project, an outreach and educational initiative led by the Cagliari Division of the National Institute for Nuclear Physics (INFN), in Italy. You can find more information here: https://dark.infn.it/eventi-pre-festival/. You can also have access to all the webinars at the dedicate YouTube playlist: https://www.youtube.com/playlist?list=PL94cdNBLY9XqD3V_YqEjVyQPXmspf2-k8.

MT: “The limit of representation, mental or real, is very important, both in communicating and teaching science. We are full of metaphors in our language which help us in imagining the world, even when the world is invisible to our sight. But without the right rational and methodological instruments, those images can create many misunderstandings. Let us think of the famous exhibit of the elastic sheet to represent and describe gravity. This is a wonderful analogy based on how we think space-time behaves when matter (or energy density) is present. But it is an analogy, not a real representation. It is a wonderful didactic instrument (and a play, too), but it brings many limits that the final users should know. Nowadays, the use of metaphors and symbols is a usual procedure in scientific communication. This is partly due to the transition we are now observing in our society, which is moving towards a purely visual and digital environment. The smartphone is always in our hands and from there stay informed about what happened around us. Science is not immune from this process and science communicators have understood it. Therefore, the use of images, both pictorial and linguistic, e.g., metaphors, is increasing. This, in turn, accommodates users’ needs of being informed but, at the same time, is leading communication to model itself to assume new (effective) forms. The audience is always at the center of the communication, as we already said”.

MS: “And that is how it is. We are seeing a multiplication of ways and channels by which science can be communicated: in addition to traditional tools - such as journal articles, radio, and TV programs—science is now being disseminated (among other things) through podcasts, video platforms such as Twitch, and of course on social media (with YouTube, Instagram, and TikTok leading the way). This is an ever-changing landscape where it can often seem difficult to find one’s way around, but it offers an undoubted advantage: there is something for everyone, for all targets. The multiplication of the offer allows anyone, from the youngest to adults, from those who are unfamiliar with science to experts, to easily find their favorite communication ‘channel’, whether it is a short video on Tik Tok or a prime-time TV documentary on the generalist television. And it is certainly positive and interesting to see that, in addition to professional popularizers and communicators, several researchers and scientists have decided to put themselves on the line in the new media, in some cases becoming real influencers of science communicators. In Italy, an interesting case is the chemist Dario Bressanini, whose videos, and popular content on the topic of food science have led to the creation of a community of hundreds of thousands of followers on major social networks.[7] This is a very interesting trend that can contribute to the hoped-for humanization of science, which we mentioned earlier, and makes inroads with very young targets”.

MT: “In the blowing of this wind of change of research and science, the school cannot be forgotten. Teaching is changing and we are now observing that the boundary between science communication and teaching is thinning more and more. Social media are becoming a place where people can be informed about everything, and researchers and teachers are using them to teach science. This is the case with

[7] https://www.instagram.com/dario.bressanini/.

YouTube, where a lot of instructional video and channels exists to explain how nature works.[8] The same is happening on Instagram[9] or TikTok, where the main goal is still to inform and not to teach. Smartphones are also becoming a pocket laboratory thanks to dedicated apps which consent to perform real experiments. This is the case of PhyPhox,[10] just to make an example. Visual resources for teaching and learning science are not only on social media but on the web in general. There are many examples of virtual laboratories which allow teachers to perform online experiments or websites which give educational supplementary material for learning science at school.[11] They offer immersive scenarios or a virtual (but quite real, we could say) reproduction of experiments easily performable in the classroom. A great innovation for the teaching and learning of science which, in turn, ensures a certain level of inclusivity in education and schools. This is not bad at all!".

6 Conclusions

The language of science is evolving, adapting to the discoveries and the audience's needs, both of experts and non-experts. The teaching and communication of science are also interesting in this phenomenon, being strictly related to the research. People are becoming more social, and the teaching of science cannot forget it. Social networks propose a visual world and science communicators should be aware of this to better spread scientific knowledge, as well as scientific cultural awareness. Images, imagination, and creativity play a fundamental role in science and research, too, and the dissemination of the latter's content is influenced by this fact. Nevertheless, if on the one hand science uses both formal (mathematics) and informal (natural language) language to communicate between experts, effective communication with the public is more oriented to the use of natural languages, where analogies, metaphors, and visual contents are predominant to simplify and explain contents. In this way, the problem of accuracy in the dissemination of science arises, and this is an issue for the science communicators.

Moreover, the science communicator is becoming more and more influential in fostering interest and motivation in the public toward scientific truth. In this process of mixing languages and cultures along the lines of social interconnection, assuming an interdisciplinary approach is fundamental. Going beyond the division of the "two cultures," the arts, or humanities on one hand and science on the other hand (Snow 2001), bringing the two worlds together instead, is very important for the common

[8] See https://www.youtube.com/@SteveMould or https://www.youtube.com/@LaFisicaCheCiPiace (in Italian) as an example.

[9] See https://www.instagram.com/emilia.science/ as an example.

[10] https://phyphox.org/.

[11] See https://www.frontiers-project.eu/gravitational-wave-astronomy/ and https://phet.colorado.edu/it/ as an example. The former offers educational resources for gravitational waves astronomy. The latter spans over all scientific topics covered in school, from physics to biology and chemistry and so forth.

goal of disseminating the scientific content, using as many tools as possible to explain complex and uncertain topics and to give reasoned, motivated, and argued interpretations (Ervas 2021). The clarity for the audience, coupled with the accuracy of the matter presented, must always be an essential starting point, valid for whatever medium one decides to use (whether "classic" or new): this has always been the main challenge in communicating science, and it must continue to be so in the future.

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