Editorial

Bridging Science Education and Science Communication Research

Ayelet Baram-Tsabari[1] and Jonathan Osborne[2]

[1]*Department of Education in Science and Technology, Technion-Israel Institute of Technology, Haifa, Israel*
[2]*Graduate School of Education, Stanford University*

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In some senses, both science education and science communication share common goals. Both seek to educate, entertain and engage the public with and about science. Somewhat surprisingly, given their common goals, they have evolved as disparate academic fields where each pays little attention to the other.[1] The purpose of this special issue, therefore, is an attempt some form of rapprochement—to contribute to building a better awareness of what each has to contribute to the other and the value of the scholarship conducted in both fields.

Before attempting reconciliation, though, it is useful to point to several of the main differences between science education and science communication research traditions. One such difference is the emphasis that they give to each of those three aspects—educating, entertaining and engaging the public. Whereas the priority for science education is, not surprisingly—education—and entertainment and engagement are a helpful by product, for the field of science communication, it is engagement that is the priority. Another difference is the critical view that some science communication research adapts towards science and scientists, a result possibly of its journalistic and sociological foundations. Science education tends to position "what science says" and "how scientists do things" as the truth that frames the model for what students should learn. In contrast, many science communication researchers position "what science says" as only one of many types of potentially relevant knowledge and "how scientists do things" as an imperfect way of making sense of the world. Furthermore, the context of the formal (school) versus informal (media) environments has strongly affected the possible methods and the subjects of study. One simply cannot give a random sample of adult television viewers a one-hour test in a natural setting which changes the nature of the questions which can be addressed. In addition, compared to science education—a field of study that emerged in the 1950s, science communication is a relatively young field.

One of the consequences of these differences is that the fields have distinct and separate emphases. For instance, one of the goals of science education is to educate the next generation of scientists—an aspect that concerns only those science communicators who work with young people, and then only to engage, stimulate and sustain interest in science. Given the significance of

Correspondence to: Dr. Ayelet Baram-Tsabari; E-mail: ayelet@technion.ac.il
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"interest" in sustaining engagement with the study of science (Maltese, Melki, & Wiebke, 2014, this is, nevertheless, an important contribution. Moreover, the field of science education has much that it could beg, borrow or steal to do a better job of sustaining student interest given the evidence of its failings (Bøe, Henriksen, Lyons, & Schreiner, 2011; Osborne, Simon, & Collins, 2003).

Another distinction is the issue of knowledge – that is what knowledge and in what form? Clearly, a glance at any set of standards or examination syllabus would suggest that this is a central concern for science education. For those engaged in science communication, however, the knowledge is contingent and what counts is contested (Layton, Jenkins, McGill, & Davey, 1993; Wynne, 1996). Both fields perhaps lack a sense of what matters. For instance, the notion that one of the goals of science education should be the production of individuals who are able to make informed decisions about scientific issues has been a long-standing goal. Ever since Paul DeHart Hurd coined the term of "scientific literacy" (DeHart Hurd, 1958), it has been an ever present theme. The report Beyond 2000 (Millar & Osborne, 1998) argued that one of the outcomes of formal education is that students should "be able to understand, and respond critically to, media reports of issues with a science component" (p12) and "feel empowered to hold and express a personal point of view on issues with a science component." Likewise, the recent US K-12 Framework for Science Education (National Research Council, 2012) argues that:

> By the end of the 12th grade, students should have gained sufficient knowledge of the practices, crosscutting concepts, and core ideas of science and engineering to engage in public discussions on science-related issues, to be critical consumers of scientific information related to their everyday lives (p24).

One response to this demand has been a long list of initiatives to place the consideration and exploration of the role of science in society on the curriculum. The major stimulus, beginning perhaps with the publication of Rachel Carson's book, *The Silent Spring* (Carson, 1963), was the realization that science no longer offered simple technical solutions to the challenges facing humanity. Rather, it was also a source of problems—a thesis developed most cogently by Ulrich Beck in *The Risk Society* (Beck, 1992). In the light of such public discourse about science and its implications, any school science curriculum that chose to maintain a hermetic seal between science and society risked irrelevance. Science not only had applications but it also had implications. In the UK, this led to early initiatives such as *Science and Society* (Lewis, 1981) which was rapidly followed by the more pragmatic *Science and Technology in Society* (SATIS) (The Association for Science Education, 1986) and then *Science for Public Understanding* (Hunt & Millar, 2000). In the US, early initiatives were the *Science Education for Public Understanding Project* that begun in 1987 at Lawrence Hall.

What these initiatives brought into being was a program of research that has explored how socio-scientific issues might be addressed in the classroom and the goals of such work (Kolstø, 2001; Levinson, 2006; Ratcliffe, 1997; Ratcliffe & Grace, 2003; Zeidler, 2003; Zeidler, Sadler, Simmons, & Howes, 2005). Others have gone further arguing that scientific literacy only has meaning as a concept of knowledge that is shared within a community which is orientated towards political action (Hodson, 2003; Roth & Calabrese Barton, 2004).

Underlying all of these initiatives has been a basic belief that democratic societies can only be sustained if individuals are enabled to participate in the societies they inhabit—a notion perhaps best expressed in a European Commission White paper (European Commission, 1995) that:

> Democracy functions by majority decision on major issues which, because of their complexity, require an increasing amount of background knowledge. For example,

> environmental and ethical issues cannot be the subject of informed debate unless young people possess certain scientific awareness. At the moment, decisions in this area are all too often based on subjective and emotional criteria, the majority lacking the general knowledge to make an informed choice. Clearly this does not mean turning everyone into a scientific expert, but enabling them to fulfill an enlightened role in making choices which affect their environment and to understand in broad terms the social implications of debates between experts. There is similarly a need to make everyone capable of making considered decisions as consumers (p24).

The simplistic assumption often made within science education is that what matters is content knowledge—an assumption that was made too initially by those with an interest in science communication. Early work exposed the apparent ignorance of the public about basic scientific ideas (Durant, Evans, & Thomas, 1989; Miller, 1983), findings which were fitted into a deficit model of the public and an outcome which emphasized the imperative of communicating knowledge (Bodmer, 1985). The deficit model, rests on the assumption that the more scientific information the public has, the more its decisions will support or agree with the scientific consensus, and the more sympathy the public would have toward science (Brossard & Lewenstein, 2009). However, empirical support for these premises is at best mixed. Survey data shows that the relationship between scientific knowledge and attitudes toward science changes substantially between specific domains of science and technology (Allum, Sturgis, Tabourazi, & Brunton-Smith, 2008). Rather research would suggest that the variance in public attitudes on controversial socio-scientific issues is better explained by values, emotions, ideology, social identity, and trust in scientific and other institutions than by scientific knowledge per se. Furthermore, the validity of many of the surveys used to measure public's knowledge of science has been questioned. As many of us know, knowledge exists on a use-it or lose-it basis so asking individuals questions about specific pieces of domain-specific knowledge is, more often than not, likely to result in a display of ignorance (Stocklmayer & Bryant, 2014). As Kitcher (2010), Bromme & Goldman (2014) and also Feinstein in his paper for this special issue point out, the public knowledge of science will always be limited. Moreover, as Ryder (2001) has shown, in a detailed examination of the knowledge necessary to interpret science in the media, content knowledge is only one of six types of knowledge necessary to critically "read" reports about science. Required as well is a knowledge of the methods of collecting data, how data is interpreted, the role of modeling in science, the role of uncertainty in science, and how science is communicated in the public domain. Thus if science education is really to deliver on its goal of educating students to be able to make enlightened choices, it needs to broaden its conception of what aspects of scientific knowledge it should address.

To give credit, where credit is due, the Next Generation Science Standards (NGSS) are based on a set of 8 scientific practices that ask students explicitly to engage in many of the aspects in Ryder's list. Missing, however from the Framework for K-12 science education, which is the basis for the NGSS, is any specification of the procedural or epistemic knowledge of science that engaging in such practices should develop. In contrast, the latest PISA assessment framework (OECD, 2012), which defines scientific literacy in terms of the competencies to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically does attempt to define a body of procedural and epistemic knowledge necessary to undertake these practices. Thus, in that sense, the work of those in science communication has forced the agenda for science education making its narrow, domain-specific, content focus hard to justify.

Notwithstanding these signs of convergence under the umbrella of "public engagement with science" (Feinstein, this issue), a central difference can be found in the implicit assumptions underlying the two research traditions. Science education makes the optimistic assumption that people who encounter science in their everyday life can, at least in theory, acquire the necessary knowledge to reach an informed, scientifically-based decision. In contrast, science communication finds people make meaning of the science they encounter in their lives using different narratives based on culturally relevant prior knowledge, that may or may not include science (Feinstein, 2012; Laslo, Baram-Tsabari, & Lewenstein, 2011). Furthermore, their ability to reach informed decision will be based not on a first hand evaluation of what is true? but on a second hand evaluation of "whom to trust?" (Bromme & Goldman, 2014).

And if science education rejects the idea that science-related decisions should be based on trust, then the challenge such findings pose to science education is how should individuals be educated to judge what is true? For instance, one issue challenging the researchers at CERN has been the issue of whether the Large Hadron Collider could potentially create a black hole swallowing the Earth. How is a local French farmer to judge the truth of such claims? Given that few if any school science syllabi even mention black holes, it is very unlikely that this individual has any of the necessary scientific content knowledge. If so, what kind of knowledge would be helpful and how should this be explored in the formal science curriculum? Like so many issues that arise in the public domain—be they the threats posed by MMR vaccinations, GMO foods, or Climate Change, too many in the public are faced with a binary choice between denial or unquestioning acceptance. What can formal education do to reduce the epistemic distance between the expert and the lay individual? The message from the field of science communication is that the answer does not lie in more content knowledge but rather in attempts to engage the public in dialogue.

What could unite both fields perhaps is a common vision of the role and importance of science in contemporary society. However, beyond fascination and awe, does either field have any sense of a grand narrative for science? Some may argue that in an era of post-modernity where the image of science has been sullied by the threats posed by technological advance, such a narrative is not needed or even counter productive. The goal of all science education or science communication should be to foster critical engagement rather than blind devotion. Nevertheless, we would contend that for all its flaws there needs to be a broader recognition within both fields of the cultural contribution that science has made to contemporary thought. Just as great literature has brought us a means of capturing and portraying the human condition, science has brought us a deep understanding of who we are and the material world that surrounds us. This it has achieved using six forms of reasoning—mathematical deduction which emerged 2000 years ago with the Greeks; experimental exploration which began in the 14th century and flourished in the Italian renaissance; hypothetical modeling to imagine a world which is too small to see or too large to imagine; categorization and classification of the world that surrounds us enabling biologists to identify distinct living species, chemists to identify elements and physicists to distinguish concepts such as heat and temperature; probabilistic and statistical thinking to identify patterns in nature and define the limits to certainty; and evolutionary accounts of the origins of species, the universe, continents, elements and more (Crombie, 1994; Hacking, 1992; Netz, 1999). We make this point as both fields offer an important contribution to the work of their common enterprise but, we would ask, do either fields share any sense of what that common enterprise might be—an issue which is also discussed in Lewentein's commentary? Our hope is that, as well as identifying the differences, the papers provided by this special issue help to build some sense of a common vision.

The Special Issue

This special issue is born of a view that there is too little dialogue today between *Science Education* (focusing on K-12 students, higher education and learning in informal environments) and *Science Communication* (focusing on interactions between the scientific community and other publics). The lack of communication between the two fields impedes the identification of shared ideas, trends, and methods. Science educators sometimes view science communication as a marginal subcategory of informal science education, while many science communication researchers frown at the very thought of studying science communication from an educational perspective (more can be found on this point about the origins of this separation in Lewenstein's commentary). It is gratifying therefore that in this issue, Blanco-López, España-Ramos, González-García, and Franco-Mariscal establish a link between the two research fields by surveying experts about the needs of adult publics in order to inform science education aimed at school students.

Another consequence of this divorce is that both fields run the risk of reinventing the wheel. For example, the field of science communication has moved from the "deficit model" to a dialogic model of engaging the public with science. The later perspective sees the communication of new public knowledge about science more as a dialogue between scientists and the society. While science communication feels that science education is still imbued with the traditional deficit-model and its negative connotations, it is science educators who made the (theoretical) change from an acquisition/transfer model of learning to a participatory/constructivist model long before it was (theoretically) done in the field of science communication. In this issue, Feinstein provides a notable example of the theoretical and conceptual depth that could have been gained from a fruitful dialogue between the disciplines.

Other theoretical constructs and research programs are waiting to be put to use. Educational perspectives, such as argumentation, could be used to study science communication, while basic communication concepts, such as framing, could prove useful for science education researchers. In this issue, Davis and Russ demonstrate how a media context and the analytical lens of framing familiar to science communication can be studied in a manner that is familiar to science education. Moreover, it is not only methods and theoretical constructs that could be shared for mutual benefit. The very basic concepts from the research on the teaching and learning of science are still rarely used when educating and training scientists to engage in science communication—a professional skill that is increasingly expected of scientists. A result is that much of this teaching is done with no learning goals in mind, and without proper assessment of the attainment of these goals (Baram-Tsabari & Lewenstein, 2013). Besley, Dudo, and Storksdieck (this issue) make an initial exploration of how such science communication "training" is viewed by scientists and what factors make them more or less likely to see its value and participate in such programs.

Overview of Articles

This set of papers very much represents an important attempt at rapprochement between the two fields. Our goal was to begin a conversation between the two groups of people who, although they often share a common goal of communicating science, ironically do not communicate well with each other. For this issue, we received 26 papers covering a diverse range of topics and the four published here are a reflection of that diversity. These are:

Paper 1: Education, Communication, and Science in the Public Sphere: Drawing Lessons for Science Education From the Lippmann–Dewey Debate

In this article, Feinstein does the community a service by reminding us that, in our obsession with the present, we forget that as novel as the issues may seem to us now, many of them have seen the light of day before. Or as Santayana said, "those who forget the lessons of history are condemned to repeat the mistakes of the past." What Feinstein has done is re-examine a debate that existed a little less than a 100 years ago between Walter Lippman, often considered the founder of American media studies and John Dewey.

What Lippman had pointed to was the problem of knowledge—that is in any public debate the level of knowledge that most of us have about the topic is very limited. Given that, how was it possible to involve the public in political debate? As Feinstein points out, this is a serious issue for science education that justifies its place on the curriculum table with the argument that it enables its students to become scientifically literate and engage in such debate. Lippman, Dewey, Shamos, and philosophers such as Phillip Kitcher would argue that science education is in self-denial. Shamos (1995); for instance argues that "if scientific literacy means knowing most of the 'basics' established by project 2061, it is doomed to fail, for at no time in the entire history of US public school education has this much knowledge of science been expected, or realised, of high school graduates." (p151). Kitcher (2010) puts it even more strongly "arguing that it is absurd fantasy to believe that citizens who have scant backgrounds in the pertinent field can make responsible decisions about complex technical matters." If so, one might ask, is the goal of enabling students to engage in critical evaluation of science either in the media or as it affects them personally hopelessly unrealistic? Feinstein's answer comes from Dewey who argues that the checks and balances on science depend on a community who have the capacity to "transcend individual limitations" as in "a diverse and well-functioning community . . . an individual does not need to know about a particular topic as long as she is meaningfully connected to someone who does." Feinstein's argument is that the message for science education is that if we wish to support students to engage with science in their lives we must show them how to work collectively. Thus rather than the futility of attempting to educate student to be scientifically literate—something which Lippman sees as a bridge too far—Feinstein finishes on an optimistic note arguing that Dewey and those who are looking at how science education can support collective group action offer a way of making education in science more relevant and enabling for its students.

Paper 2: Key Aspects of Scientific Competence for Citizenship: A Delphi study of the Expert Community in Spain

In this article, Blanco-López, España-Ramos, González-García, and Franco-Mariscal contribute to the longstanding goal of linking the content and aims of science education to what citizens need in order to participate effectively in a society. The authors empirically assessed the extent of the consensus in Spain regarding the principal aspects of scientific competence that citizens should possess using a Delphi process involving scientists and engineers, researchers and private sector scientists, philosophers of science, science educators, and science communicators. This type of approach raises two issues. First, asking about present day needs in order to plan present day curriculum means inherently accepting and expecting a curriculum that would serve the needs of the past. However, since true prophecy is rare these days this strategy has merit, and might be boosted by insights from futures studies. The second issue involves surveying experts in order to determine lay people's needs. Here we have to ask—who are the experts on the needs of layman? Shouldn't we draw on the experiences of non-technical publics when trying to address their needs? This dilemma presents yet another potentially useful meeting point between science communication research which looks at authentic interactions of laypeople with science related issues and science education research which conceptualizes how such interaction should ideally be conducted (Laslo et al., 2011).

The analysis by Blanco-López, España-Ramos, González-García, and Franco-Mariscal, concludes with a non-trivial result: the leading aspects identified by the panel of experts cover a range of general skills, attitudes, and values that are not exclusively related to the sphere of science and technology (e.g., Critical attitude/thinking or Ability to work as part of a team). The authors see them as "core skills, attitudes, and values that lie at the heart of personal education." Moreover, the experts generally rated aspects related to attitudes and values higher than to those referring to knowledge. The suitability of such expert advice can now be studied against the background of real-world science-related situations as well as the science education experience of teaching competences independent of specific content.

Paper 3: Scientists Views of Communication Training

Besley, Dudo, and Storksdieck take a different angle on the science and society issue by looking at the scientists, rather than the rest of society, as those who have some learning to do. Building on a science communication tradition of research, this issue is not referred to as teaching and learning activities, but as "training." Within the context of public engagement with science, sharing knowledge in ways that interest laypeople is still a key element of science communication by scientists, but the emphasis shifts from focus on scientists' information transmission skills towards getting scientists to think about science communication as a dialogue with the public. Therefore, there are science institutions that shift from providing media training (aimed at speaking to journalists) towards communication training aimed at helping scientists to foster open dialogue with the public, partly in order to reach wider publics who are not attentive to science. Such a need for a change in attitude and skills of professionals brings to mind the wealth of research about teacher's professional development, which is unfortunately completely alien to science communication studies.

Besley, Dudo, and Storksdieck explored scientists' views about training to: (1) make their science messages understandable; (2) build trust and credibility; (3) demonstrate that one listens to the public; (4) demonstrate that one cares about the public's views; and (5) frame messages to resonate with audiences' pre-existing values. The tension here is between what seems to the scientists to be ethical and doable (e.g., make their message understandable) and what science communication research dims effective (e.g., frame their message to resonate with the audience). The authors wish to use this understanding of the value scientists might see in communication training, and the concerns they might have about its ethicality and appropriateness in order to support training design and recruitment.

A sobering finding of this paper is that though willing to involve themselves in some kinds of communication training, the scientists surveyed cannot be counted on as active science communicators. Although seeing the value in these activities they rated their willingness to engage with the public online fairly low, were only slightly more willing to reach the public via the media, and showed moderate willingness at best to engage the public face-to-face. Improving these attitudes is relevant to teacher-scientists partnerships and other designed activities involving scientists. It is refreshing to think of the scientists as someone who could and should develop better knowledge, attitudes and skills in these activities.

Paper 4: Dynamic Framing in the Communication of Scientific Research: Texts and Interactions

In this paper, Pryce Davis and Rosemary Russ explore how a particular text communicating a piece of research is constructed and altered as it is adapted and summarized for a lay audience. The "text" is a piece of research looking at the prescription of proton pump inhibitors to veterans. These drugs are commonly used to reduce gastric acid and the research finds that the drugs are often prescribed at higher doses than necessary and, moreover, remain prescribed for longer than necessary. The research is picked up by the University news service and the study follows in detail, using extensive interviews, how the research is "read" by the reporters and then how it is translated into a form to be communicated to a wider audience. The work draws on the theoretical construct of framing—that is the idea that any texts contains elements which organize how it is perceived—to explore how this research is framed for its intended public and why those choices are made by the reporters. By focusing on certain elements, the reporters manipulate what individuals notice and attend to. These authors argue that the construct of framing is significant too for the field of science education in that science teachers frame the science they present to their students. In this paper, the authors show how the concepts are initially framed in the original publication itself using economic arguments, raising issues of uncertainty and the commonness of prescription to justify the importance and role of the research. They then explore how certain of these frames are picked up on by the news reporters such that the article is reframed with more emphasis given to some frames rather than others such as the economic frame.

The paper then turns to look at how these frames are read and interpreted by one member of the public who did not study science beyond high school. The work shows how this individual draws on his own frames to interpret aspects of the research. Making detailed comparisons between the intended message of the researcher and what might be called the message ultimately attained by the lay reader, the authors argue that framing is a dynamic process where the message can never really be fixed. The implications for science education are that we may need to teach students to identify the frames embedded in a text and to switch between them if they are to make sense of what the text is trying to communicate. For science communicators, the authors argue that there is a need to employ a range of frames to highlight different features of the research. Alternatively, if they wish to sustain a single frame, then this needs to be repeatedly cued throughout the text. The work adds to the field of science education another piece on the role of framing and its potential significance in how meaning is to be constructed from science texts. For science communicators, where the concept of framing is well-established, what it offers is some insight into the dynamic nature of the process of framing and the tacit and unpredictable nature of the frames that the public might adopt. The authors use the findings to argue that the concept of framing is something that has a potential to act as bridge between the two fields of science education and science communication.

Finally, we both wish to acknowledge Stephen Norris, one of the original initiators of this special issue who tragically passed away a year ago in February 2014. As a philosopher, Stephen, brought to the field of science education an analytic lens that was both clarifying and refreshing. He had the philosophers' characteristic of asking hard questions of our community about the goals, values and concepts that guided its work. In that respect, one of his most seminal contributions was an examination of what is really meant by the concept of "scientific literacy" (Norris & Phillips, 2003). This paper was the product of a long line of work beginning with an exploration of how science is communicated and the way in which people construct meaning from such texts (Norris & Phillips, 1994); whether the goal of intellectually independence is truly achievable (Norris, 1997); and more recently how adapted primary literature can be used within science education (this work is summarized in his last book: Yarden, Norris, & Phillips, 2015). Stephen Norris was somebody who recognized that the first duty of an intelligent man is to ask the hard questions that others had avoided. Undoubtedly, that was part of his intent in initiating this special issue. We can only hope that what is offered here would have met his expectations.

Endnotes

[1] A recent exception is the publication of the *International Journal of Science Education Part B*: *Communication and Public Engagement* that began in 2011. It serves the needs of science educators whose research interests have already expanded beyond the realm of school science, although they still define themselves as within science education research (Ogawa, 2011).

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