doi:10.2533/chimia.2025.717 Chimia 79 (2025) 717–723

Communicating Chemistry Innovation to the Public

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Abstract: The thesis of this study is that communicating research achievements is an important component of research and technology management in chemistry research. New chemical products and new synthetic and analytical chemical processes often have a broad and lasting socioeconomic and environmental impact. Besides differentiating chemistry from other basic sciences, this trait is reinforced by the sustainability challenge to make economic growth compatible with long-term well-being for all people and the environment. Following a succinct review of previous scholarly work on chemistry communication, we identify the key benefits provided to chemistry scholars by the effective communication of chemistry innovation to the public.

Keywords: Chemistry innovation · Communicating chemistry · Open science · Research management

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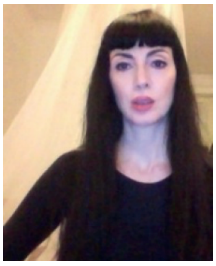

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1. Introduction

Amid the so-called 'basic sciences' (mathematics, chemistry, physics, and biology), chemistry is the only one which produced a global, huge, and diversified industry.[1] The industry's products and productions have a broad societal impact, often of global relevance. Hence, one would expect a vigorous public engagement activity of chemistry scholars. "*When the public em-*

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braces what happens in research labs, they will support federally funded research" written in 2018 by academic chemists based in the USA.[2] Similarly, recognizing "*the value and importance of chemistry in addressing societal challenges and its potential to stimulate wonder and interest about our world*" in the early 2010's the National Science Foundation of the same country asked the National Academies of Sciences, Engineering, and Medicine "*to develop an evidence-based framework to guide chemists' communication activities in informal settings*".[3] The outcome was a book including a five-element framework for effective public communication activities for chemistry.[3] Previously, in 2011, writing in a new chemistry journal created in 2009 by the Nature Publishing Group, two academic chemists also based in the USA had concluded that for engagement-focused communication it is "*impossible to predict in advance which strategy will be the most effective*".[4]

In the subsequent decade communication with the public through the 'social media', namely social networking websites today used by billions of people worldwide, will emerge as the new key communication means to engage with the public also in scientific research,[5] often combined with the use of personal academic websites.[6]

The topic of chemistry communication has often been dealt with by speakers at the Ecsite conferences, a series of annual meetings of science engagement professionals in Europe, organized since 1989 by the European Network of Science Centres and Museums.[7] Very few scholarly studies, though, have been published on communicating chemistry to the public (see below), and even less on publicly communicating chemistry research. In 2019, the American Chemical Society (ACS) published Communication in Chemistry following an ACS-sponsored symposium. Comprising 18 chapters written by research chemists from numerous universities based in both the USA and Canada, the book had the purpose 'to provide examples of chemists as communicators to both students and the public'.[8]

In general, chemistry is a subject difficult to learn,[9] and even more difficult to communicate to the general public due to the abstract and symbolic nature of the science.[10] Worsening matters, chemists tend to adopt the counterproductive one-way top-down, communication process.[11,12] On the other hand, new chemical products and new synthetic and analytical chemical processes often have a broad and lasting socioeconomic and environmental impact. Besides differentiating chemistry from other basic sciences, this trait is reinforced by the sustainability challenge to make economic growth compatible with long-term well-being for all people and the environment.

Filling a gap in the literature, this study suggests avenues on how to conduct said communication based on the methodological autonomy of chemistry as scientific discipline.[10]

2. Method

We first identify previous work in chemistry communication in the literature. Hence, we critically analyze the outcomes of the bibliographic search. We conclude identifying the key benefits provided to chemistry scholars by the effective communication of chemistry innovation to the public. In December 2024, we carried out two bibliographic searches in the literature in English indexed by Scopus research database using the queries 'communicating chemistry' and 'communication of chemistry' within 'Article title, abstract, keywords' extended to all time. The former search returned 19 documents published in journals between 1979 and 2022.[13] The latter returned 10 documents published in journals between 1974 and 2024.[14] Both search outcomes were inspected. Polishing the first set by eliminating one article (not pertinent), two editorials, and two other documents (one review of general chemistry books, and one conference paper), the list shrank to 14 documents listed in Table 1.

Polishing the second set by eliminating two studies not relevant ('Gap junctions, connexins and sudden death caused by coronary heart disease', 2004, and 'Method for relating the structure and properties of chemical compounds', 1974), the list shrank to 8 documents (Table 2).

3. Results and Discussion

3.1 *Few Works, Rarely Cited*

The outcomes of the bibliographic searches summarized in Table 1 and Table 2 are revealing.

First, the field of chemistry communication is relatively new, with the first study describing an exhibition on everyday chemistry published in 1986 (entry 13 in Table 1).

Second, with a few exceptions for articles published in *Nature Chemistry* and *Tetrahedron*, neither elite chemistry journals such as *Angewandte Chemie* nor elite general science journals such as *Science* or *PNAS* publish studies dealing with the topic of chemistry communication.

Third, the few articles published on the topic are poorly (or never) cited. The only study with a significant number of citations (52) was published by *Nature Chemistry* in 2011 (entry 9 in Table 1). This does not mean that the studies on chemistry communication do not attract scholarly interest, but only that the scholarly debate in the field is nearly non-existent. For example, the openly accessible study '*Beyond Exploding Balloons - Bringing the Science of Chemistry to the Public*' published in early 2022 by the *Canadian Journal of Chemistry* by the end of 2024 had never been cited, but it was downloaded 769 times.

The contrast with physics, the scientific discipline closest to chemistry, is evident. The writings (novels and textbooks) of Asimov, Sagan, Feynman, and Gamow motivated generations of students to start undergraduate studies in physics. Physicists, in general, are well aware of the relevance of communicating physics to the public.[15] The American Physical Society (APS), for example, operates a Joint Network for Informal Physics Education and Research whose members share best practices and track the impact of public engagement.[16] In physics, furthermore, research articles on physics communication and public engagement are regularly published in old and prestigious journals such as *Physics of Plasmas* established in 1958.[17] Finally, prestigious general science journals such as *PLOS One* regularly publish articles on physics public engagement even in particle physics,[18] that are highly read and debated in the scholarly literature. The latter study,[18] for instance, accrued 56 citations in 8 years.[19]

3.2 *Public and Chemistry*

Prior to 2014 a survey carried out in Great Britain on behalf of the Royal Society of Chemistry (RSC) to investigate and understand the public attitudes to chemistry. Chemists were not aware that even in a industrially advanced country hosting one of the world's oldest and most important chemistry schools, the public confused 'chemist' with 'pharmacist', with 76% of respondents (2,104 adults aged more than 16) mentioning a pharmacy when answering 'where do you think chemists work?'[20]

The objectives of communicating chemistry research achievements to the public are often wrongly set by research chemists because they assume that the general public is interested in their sophisticated findings. In general, however, this is not the case. The public will only be interested when said findings are relevant to their lives and wellbeing. Assuming that the public would be interested in chemistry is a common mistake that can make the communication process irrelevant and even counterproductive. The way to make the communication of chemistry research findings relevant and purposeful to the public is to relate said findings to the interests of people and to the real world:

Table 1: Articles dealing with *'communicating chemistry'* within 'Article title, abstract, keywords' indexed in Scopus (source: Scopus, 2024).

Entry	Authors, Document title	Journal/Book	Year (citations)
1	J. Farrell, A. S. Wahba, 'Beyond exploding balloons – bringing the science of chemistry to the public'	*Canadian Journal of Chemistry*	2022 (0)
2	E. Howell, S. Yang, C. M. Holesovsky, D. A. Scheufele, 'Communicating chemistry through cooking and personal health: everyday applications increase perceived relevance, interest, and self-efficacy in chemistry'	*Journal of Chemical Education*	2021 (6)
3	E. Kunz Kollmann, M. Beyer, E. Howell, A. Anderson, O. Weitzman, M. Bequette, G. Haupt, H. Velazquez, S. Yang, D. A. Scheufele, 'Collaboration for chemistry communication: Insights from a research-practice partnership'	*Journal of Science Communication*	2021 (0)
4	B. A. Reisner, J. L Stewart, 'The literature discussion: a signature pedagogy for chemistry'	*ACS Symposium Series, 1370*	2020 (5)
5	G. L. Crawford, K. D. Kloepper, J. J. Meyers, R. H. Singiser, 'Communicating chemistry: an introduction'	*ACS Symposium Series, 1327*	2019 (2)
6	T. Whitcombe, 'Why communicating chemistry can be complicated'	*ACS Symposium Series, 1327*	2019 (1)
7	R. Vladusic, M. Ozic, 'Pre-service chemistry teachers' understandings of symbolic representations used in chemistry instruction	*Turkish Online Journal of Educational Technology*	2016 (1)
8	M. M. Kirchhoff, 'Communicating chemistry in informal environments: a framework for chemists'	*Journal of Chemical Education*	2016 (7)
9	M. R. Hartings, D. Fahy, 'Communicating chemistry for public engagement'	*Nature Chemistry*	2011 (52)
10	T. Velden, C. Lagoze, 'Communicating chemistry'	*Nature Chemistry*	2009 (19)
11	L. Cardellini, 'Communicating chemistry from molecules to international efforts: an interview with Peter Atkins'	*Journal of Chemical Education*	2008 (0)
12	M. Dunstan, P. Bassinger, 'An innovative model: Undergraduate poster sessions by health profession majors as a method for communicating chemistry in context'	*Journal of Chemical Education*	1997 (20)
13	D. Ucko, R. Schreiner, B. Shakhashiri, 'An exhibition on everyday chemistry: communicating chemistry to the public'	*Journal of Chemical Education*	1986 (10)
14	L. W. Fine, 'Communicating chemistry. A planning proposal for changing the chemistry curriculum'	Journal of Chemical Education	1994 (0)

Table 2: Articles dealing with *'communication of chemistry'* within 'Article title, abstract, keywords' indexed in Scopus (source: Scopus, 2024).

Entry	Authors, document title	Journal/Book	Year (citations)
1	G. Chiacca, V. Domenici, 'Perception of chemistry and chemistry Education: a case study and some reflections'	*Substantia*	2024 (0)
2	R. Ciriminna, A. Scurria, M. Pagliaro, 'Social media for chemistry scholars'	*ChemistryOpen*	2023 (1)
3	R. Chalupa, K. Nesměrák, 'Chemophobia and passion: why chemists should desire Marcel Proust'	*Monatshefte für Chemie*	2022 (2)
4	M. Guerris, J. Cuadros, L. González-Sabaté, V. Serrano, 'Describing the public perception of chemistry on twitter'	*Chemistry Education Research and Practice*	2020 (13)
5	B. N. Christian, E. J. Yezierski, 'A new chemistry education research frontier'	*Journal of Chemical Education*	(10)
6	A. Day, A. Williams, C. Batchelor, R. Kidd, V. Tkachenko, 'Utilizing open source software to facilitate communication of chemistry at RSC'	*Open Source Software in Life Science Research: Practical Solutions to Common Challenges in the Pharmaceutical Industry and Beyond*, pp. 63–87	2012 (3)
7	D. L. Illman, 'Engaging students in science communication an experiential learning model'	*ACS Symposium Series 1037*	2010 (2)
8	R.-E. Eastes, 'Communication of chemistry: Natural and chemical? | Communication de la chimie: Naturel et chimique?'	*Actualité Chimique*	2008 (1)

"*both real world issues people care about (e.g. food shortages, clean water and renewable energy) and the real world that people inhabit day-to-day (e.g. how food is processed and cooked)*".[20]

Writing in 2016 a openly accessible study published in *Chemistry International*, Edwards and coworkers rightly emphasized the need for chemists willing to communicate chemistry to the public to start from evidence, and replace the will to 'teach chemistry to the public'[21] with communication capable to show the potential of chemistry 'to improve our lives'.[21] In the words of Edwards, communication manager at the RSC:

"*Our efforts need to be less of a one-way lecture and more of a conversation. To communicate effectively we need to know our audience, their motivations, and their existing level of knowledge. We have to ask questions, find out where they are coming from and what they are worried about, and work out what they want to get out of the conversation. One-way 'engagement' is not engagement at all.*"

"*We should also try and find out what the other person is interested in and relate our work to that. For example, in our workshops we had a hugely positive response to engagement materials around the concept of everyday chemistry - things like cleaning and baking… After viewing our video that related chemistry to baking, one participant said, 'It doesn't feel above me now… it feels parts of everything, not an academic subject*,'"[21]

Said evidence emerged from the seminal public survey carried out in Britain in 2014–2015, whose main outcomes are:

1) People barely know what chemists do and who they are;
2) The public is only interested when chemistry facts recounted are connected to their daily life.

Following the public survey on how chemistry is actually perceived by the public, the RSC in 2015 published a 9-page communication toolkit.[22] Showing evidence of the absence of intellectual debate amid research chemists, this valued resource (still fully available online for free download) is nine years later mentioned in two web pages and in two PDF documents indexed by Google search engine.[23] The toolkit, in its turn, has been mentioned once on Twitter,[24] the social network most frequently used by scientists to share research outcomes and ideas with the public and with peers.[25]

The aforementioned study of Edwards and coworkers published in 2016,[21] in its turn, to date (including the preprint of the present study) has been cited nine times.[26] This paucity of intellectual debate amid chemistry scholars is in line with the 'variety of concerns suggestive of some underlying uncertainties and self-doubts'[27] of chemists identified by Heylin in the late 1990's. By communicating to the public socially relevant research achievements, research chemists may overcome also said 'uncertainties and self-doubts'.

3.3 *Benefits of Communicating Research Achievements*

The following examples illustrate how communicating socially relevant research chemistry achievements to the public provides research chemists with two main benefits: new collaborations with research groups and companies; and raising the social status of chemistry, a benefit whose positive consequences go well beyond the aim 'to secure public support to taxpayer money funding research'.[2]

Prior to starting public engagement activities concerning research achievements, however, a word of caution may be useful. In Ackoff's words:

"*It is much better to do the right thing wrong than the wrong thing right, because when errors are corrected, it makes doing the wrong thing wronger but the right thing righter*".[28]

Doing 'the wrong thing right' here is to set and pursue wrong communication objectives based on the naïve assumption that the public should be 'interested in science' and 'educated' by disseminating knowledge devoid of social relevance. When such dissemination activities based on unfounded premises is done, using 'effective communication guidelines' or quality management tools such as the plan-do-check-act (PDCA) cycle (Fig. 1) for continuous performance improvement,[29] the outcome will only result in 'doing the wrong thing wronger'.

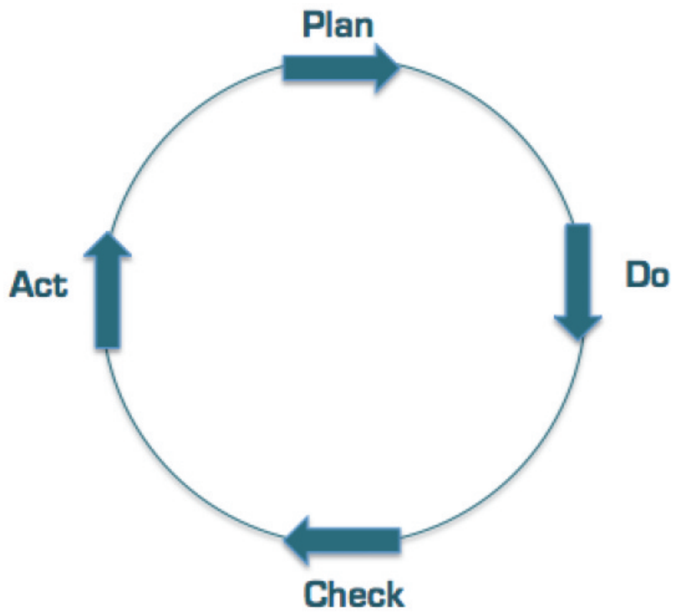

Fig. 1. PDCA cycle for continuous performance improvement.

3.3.1 *New Collaborations*

On May 4, 2022, a national radio station in Italy broadcasted an interview with one of the authors (M. P.) reporting the joint discovery of the new 'CytroCell' micronized cellulose obtained from industrial citrus processing waste.[30] The whole broadcast lasted 7 min and 51 s, with the interview taking slightly more than 5 min. No jargon terms were used, and the journalist emphasized how the peel of a daily life product known to most listeners (the orange fruit) upon squeezing to extract the orange juice actually provided the source of the cellulose. The team, he further explained, used "*cavitation, the same phenomenon that shapes air bubble around the propeller of a boat rotating at high speed, and uses only water and electricity*".[31]

A listener to the radio broadcast[31] had a friend with a relative who was a PhD student at Milan's Polytechnic working with microcrystalline cellulose and nanocellulose as lime (a construction material) additive. He listened carefully and the subsequent day informed his relative. Three weeks later, on May 27th 2022, the researcher interviewed by the radio received an e-mail from the Polytechnic's chemistry professor (S. Goidanich) mentoring the aforementioned PhD student in Materials engineering, enquiring about possibility to collaborate.

Collaboration was established and remarkable results were obtained. The newly extracted lemon CytroCell is an excellent lime additive, when added to the lime precursor in small amounts largely improves the lime carbonatation rate.[32] The CytroCell in turn is derived from lemon industrial processing waste, and not from 'peel' as is often read in the citrus biorefinery literature. Industrial citrus processing waste (CPW) indeed is comprised of peel, seed, and inner fruit parts residue of the industrial squeezing process. A citrus processing company based in Sicily started to supply the CNR authors' laboratories in Sicily (and that of F. Meneguzzo in Tuscany) with CPW derived from organically grown fruits. One company's manager and co-owner contacted one of us upon reading in August 2019 in a newspaper widely circulated and read in eastern Sicily about the joint discovery.[33] The manager visited the CNR Labs in Sicily shortly afterwards, and since then his company has kindly donated the CPW obtained from several citrus fruits (lemon, red orange, grapefruit, blond orange) used to extract the CytroCell and the IntegroPectin biomaterials. Their remarkable biological, physical, and structural properties are now reported in over 30 research papers published between 2019 and early 2025. Dispersed in water and added to polymerizable ionic liquid in small amounts (1 wt.%), for example, lemon CytroCell turns otherwise unstable transparent membranes into an exceptionally stable transparent membrane suitable for producing large area anion exchange membranes.[34]

In the late 1990's the British Broadcasting Corporation (BBC, the government television of Great Britain) broadcasted an interview on 'doped' sol-gel glasses with their inventor, the Israeli chemist David Avnir.[35] The interview was part of one episode of Tomorrow's World, a long-running television series on new developments in science and technology transmitted on BBC1 for 38 years between 1965 and early 2003. The journalist and the chemist sat on a beach in Israel. In less than one minute, the inventor explained the function in practice of a sunscreen lotion formulated with sol-gel microspheres functionalized (doped) with an organic species adsorbing the UV rays.[36]

A few months later, also thanks to the significantly enhanced visibility of the technology, the spin-off company established by the inventor along with a former doctoral student, raised enough private capital to fund construction of the first plant in Israel to manufacture the silica-based 'UV Pearls' subsequently supplied to cosmetic companies to formulate safe sunscreen lotions (the encapsulation of the active UV adsorbing organic molecules within silica microspheres reduces the amount of free radicals generated and keeps the organic filters on the top layers of the skin, decreasing the risk of contact dermatitis). In the subsequent two decades, the company became a leading company in nanomedicine, with the first innovative acne treatment (based on tretinoin and benzoyl peroxide microencapsulated within silica-based microcapsules to stabilize tretinoin from being degraded by benzoyl peroxide and to slowly release each of the active drug ingredients over time) approved after many years.[37]

These two examples alone show why, when communicating with the public, scholars should not underestimate the importance of communicating *via* mass media with the general public. Communicating chemistry research achievements to the general public audience *via* a plain and attractive language may lead to new scientific collaborations as well as to new collaborations with companies, investors, and public institutions interested in the communicated research. The general public, indeed, includes shop floor workers and the elderly along with entrepreneurs, scientists, politicians and many other categories of people.

3.3.2 *Raising the Social Status of Chemistry*

Chemistry is by far the science with the most widespread and profound impact on the daily life of people since the early 1800's when first biobased chemical productions became widespread, to be replaced in slightly more than a century first by carbon-based productions starting from acetylene, and then by oil-based industrial productions starting from ethylene. Regardless of its unique social and economic relevance, however, chemistry practitioners suffer from a poor social status that makes them unknown to the general public even in the country where industrial manufacturing of chemical products actually started in the early 1800's (Great Britain).

Communicating the achievements of chemistry research to the public contributes to change this unfortunate situation. From the use of a simple and direct language ('speak as a parent, a sports fan or a gardener, not as a chemist')[38] to the use of illustrations and videos, there are many ways to effectively communicate said findings. Readers can access a vast and updated literature on science communication that includes excellent books[39,40] and scholarly journals (*Journal of Science Communication*, *Science Communication*, *Public Understanding of Science etc.*).

Another way to increase the social relevance of chemistry resides in the ability to establish connections between chemistry and other subjects such as history and economics, placing chemistry in the broader context of culture. Explicitly formulated by Paoloni in the early 1980's for chemistry,[41] this idea will be expanded by Levy-Léblond two decades later: science (and not only chemistry) urgently needs to be brought back into culture from which it separated during the second half of the 1900's due to increased specialization.[42]

Aldo Steinfeld has been a professor of thermodynamics at Zurich's Polytechnic ETH until late 2023. The scientist advanced the solar energy harnessing technology based on concentrated solar power coupled to catalysis to produce hydrocarbons from only H_2O and CO_2 feedstocks up to the point to make it technically and economically viable.[43] On May 10, 2024 he posted on Twitter the news of the world's first industrial-scale solar fuel plant (Steinfeld, 2024).[44] To announce the forthcoming inauguration of the plant 'later this summer', he illustrated the tweet with a photograph wherein he and the co-chief executive officer of the company Synthelion hold a flask with solar-made synthetic fuel (Fig.2).

Fig. 2. Tweet from Aldo Steinfeld, ETH Zurich, posted on May 10, 2024.

At the bottom of the tweet, Steinfeld inserted a link to the company's website. Accessing the linked web page, one learns that the plant (dubbed 'DAWN') is located in Jülich, Germany, and serves to demonstrate the solar fuel technology and its robustness at industrially relevant scale, whereas future solar fuel plants, such as the one already planned in Spain, will exceed the size of the German plant and offer significantly higher production capacity.

Accessing the Twitter account of the company, one can easily find a tweet where the company shows where such solar fuel plants could be built in the future 'as our technology needs a lot of sunshine'.[45] Since solar energy is one of the most abundant renewable energy resources and is evenly distributed around the world, solar fuels can be produced around the globe. In brief, two tweets show members of the public, users of Twitter (now X), that chemical and engineering research rather than causing further environmental damage, may actually benefit the environment and society by completely new, ecofriendly technologies relying, such as in this case, on abundant, clean and free solar energy. Similar use of social networks has the ability to shift the public perception of chemistry research as something that practically benefits society.[46]

3.3.3 *A Technoscience Unknown to the Public*

As shown by the survey commissioned by the RSC in Britain in 2014, the work of chemists is worse than ill-considered by the public: it is entirely unknown, leading the RSC communication manager to suggest that rather than 'I am a chemist' chemists would be better saying 'I am a scientist, working in chemistry'.[21]

The general public is interested in chemistry research findings when said discoveries are relevant to their lives and wellbeing. The way to make communication of chemistry research findings to the public relevant and purposeful, thus, is to relate chemistry discoveries to the personal life of people and to the real world.

Chemistry is a technoscience, namely a science whose practitioners besides investigating existing substances, create and investigate new ones, such as polymers derived from olefins and ultimately from oil. Industry selects said chemical substances based on their ability to meet societal (medical, agricultural, industrial, transport, construction *etc.*) needs and start manufacturing them.[47] As such, chemicals are intermediate substances 'between nature and society'.[47] For this reason, communicating chemistry with the aim to bring chemistry into the public debate "*does not merely consist of doing publicity, but actually in promoting clarifications having to do with the implications of productive and societal choices when assimilating products from its industry*".[48]

For example, while carrying out research on biofuels at the University of Amsterdam in 2010, Rothenberg and Alberts accidently discovered the first biobased thermoset polymer: the polyester resulting from the polycondensation reaction between citric acid and glycerol.[49] A spin-off company was established to commercialize the production of the new polymer. When meeting the press along with the board of the University of Amsterdam, they presented the new bioplastic sitting around a table made from 'glycix'.[50]

Communicating with the public *via* the press, Rothenberg focused on the environmental advantages offered by the new biobased resin: "*Glycix is 100% biodegradable. With water it breaks down into its monomers, i.e., glycerol and citric acid, two compounds which are completely natural and will be absorbed in the natural cycle*".[50] Recently, the first kitchen made from wood panels containing the novel bio-resins as a binder that can be reused, refurbished, or recycled was commercialized in the Netherlands.[51]

Traditional construction materials for kitchens (as well as for furniture and cabinets) consists of pressed wood products, such as particleboard, plywood, and fiberboard that contain formaldehyde-based resins to make them stable and durable. Formaldehyde, alas, is toxic to man, plants, and animals. A recent systematic review of the geographical and temporal distributions of indoor formaldehyde concentrations in residences, schools, and offices in China recently found that the concentration of indoor formaldehyde during 2011–2015 in newly renovated residences, schools, and offices were 153 $\mu g/m^3$, 163 $\mu g/m^3$, and 94 $\mu g/m^3$, namely 82%, 46%, and 91% higher than the maximum threshold of 100 $\mu g/m^3$.[52] The threshold, furthermore, has been subsequently reduced to 80 $\mu g/m^3$.

4. Conclusions

In conclusion, a bibliographic search of the literature in English on Scopus research database using the queries 'communicating chemistry' and 'communication of chemistry' within 'Article title, abstract, keywords' extended to all time, unveiled that the field of chemistry communication is relatively new, with the first study describing an exhibition on everyday chemistry published in 1986 (entry 13 in Table 1). With a few exceptions limited to *Nature Chemistry* and *Tetrahedron*, neither elite chemistry journals nor elite general science journals showed interest in publishing studies dealing with the topic of chemistry communication. Finally, the few articles published on the topic (chiefly in chemistry education journals) are poorly (or never) cited, showing evidence of paucity of intellectual debate amid research chemists on this important aspect of their work.

On the other hand, as briefly shown in this study through selected examples, communicating chemistry innovation to the public provides chemistry scholars with two major benefits: i) enhanced case for collaboration (with companies, public institutions, investors, and other research teams); and ii) raising the social status of chemistry. Other important benefits include the fact that evaluation of scholarships increasingly takes into account also service, and no longer achievements in research and teaching only.[53] Furthermore, we agree with physicists at the American Physical Society: the reflective thinking needed to prepare for communicating research achievements aids in streamlining concepts and can even lead to new ideas for research 'in a way that differs from traditional mechanisms'[54] such as examining the work of peers or discussing with the research team's members.

This study, whose preprint was posted in *ChemRxiv*,[55] has its own limitations. Outcomes of the bibliographic investigations in Table 1 and Table 2 are incomplete. For example, the aforementioned Communication in Chemistry edited volume[8] includes numerous chapters part of scholarship related to communicating chemistry to the general public. One on how to use structured presentations to tie chemistry course content to everyday contexts;[56] another on the use of art to communicate chemistry;[57] and others. This inconsistency most likely stems from the fact that all said contributions are book chapters. The latter are often poorly indexed by research databases, when compared to journal research articles.

Asked to provide advice to amateurs, photographer and journalist Robert Capa said "*tell them to like people and let them know it*".[58] The same advice can be given to research chemists concerning the need to communicate socially relevant achievements in chemistry research to the public. The examples selected for discussion in this study show that communicating achievements in chemistry research has the intrinsic ability to further raise the status of chemistry promoting the role of chemistry innovators as 'social entrepreneurs'.[59] The creative work of research chemists indeed may result either in new product (material) production processes or in completely new products meeting industrial, health, environmental, agricultural or technology specific needs, eventually benefiting the whole community and, in certain cases, mankind. When this is the case, chemistry research achievements need to be communicated to the public, because the public ultimately is the beneficiary of chemistry innovation.

Acknowledgments

We thank all our former and current Master and PhD students for what we learned also concerning communicating chemistry research to the public during prolonged mentoring work.

Received: February 7, 2025

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