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Social Media for Chemistry Scholars**

Rosaria Ciriminna,*[a] Antonino Scurria,[b] and Mario Pagliaro*[a]

Used by nearly 60% of the world's population, social media are highly interactive websites ("platforms") today widely used also by researchers. This perspective aims at identifying the main benefits of social media utilization by chemistry scholars with respect to the three main dimensions (research, education and societal service) of scholarly activity. The main risks arising from the use of social media, as we suggest in the conclusions, must be managed and new education on their purposeful utilization should be planned and delivered

Introduction

Generally allowing users to publish ("post") text, video and audio files and receive comments by users of the same website, "social media" are Internet-based websites ("platforms" or "channels") allowing users to communicate with each other either in real-time or asynchronously.[1] Some, such as Twitter or Facebook, are social networking sites, others, such as Instagram or YouTube, are media sharing sites. As of early 2022, nearly all Internet users (4.62 billion out of 4.95 billion people) used also social media (58.4% of the world's total population, growing at >10% yearly rate).[2]

Given these figures, it is perhaps not surprising that by surveying 2,500 scholars who used these relatively new communication channels, Ian Rowlands and co-workers found in 2010–2011 that in research settings social media tools were mainly used for collaborative authoring, conferencing, and scheduling meetings, having become "important complementary channels for disseminating and discovering research".[3]

In 2013–14, Kimberley Collins and co-workers surveyed 587 research scientists from 31 countries, mainly life science researchers, to assess their use of social media.[4] More than 50% of those responding used social media, chiefly to share research achievements and for exchanging knowledge with colleagues in a timely manner, much faster than having to wait until a research paper is published to receive feedback. Of those using social media, nearly all (78%) were between the ages of 21 and 39, namely were young scientists.

Russian scholars described, in 2020, how Russian universities use the VKontakte social network to effectively support the educational process in various disciplines, including history.[5] Scientists, and biologists in particular, were found to largely use academic social networks such as ResearchGate to foster collaboration and to accelerate the rate of discovery more than a decade ago.[6] By mid-2022, the latter networking website had reached more than 23 million users (1.5 million of whom are chemists).[7]

Little research has been devoted to social networks and chemistry, chiefly on the use of social media in chemistry education.[8] Allowing nearly simultaneous discussions impossible in a classroom setting, for example, Blonder and Rap found that social networks provide *new* opportunities for resolving communication and cognitive conflicts that consequently can lead members of the social "community" to learning chemistry.[9]

Writing in early 2022, the editor of a large chemistry research publisher noted how there was "a large and flourishing community of chemists on Twitter", even though "many researchers still see social media as a waste of time".[10]

Yet, four years before, Carolyn Bertozzi explained that the reasons she knew "what is happening in so many labs, places and fields: most of the time, I learned it on Twitter".[11] In 2022, Bertozzi was jointly awarded the Nobel Prize in chemistry "for developing click chemistry and bioorthogonal chemistry".

"I never set out with the intention to network or meet new people through Twitter. However, as I started to share my thoughts and engage with other people through their posts, I found myself drawn in and embraced by a community that I hadn't even known existed"[12] wrote Jennifer Heemstra in 2020 offering a perspective on the benefits offered by Twitter to research chemists.

In 2017, Clarissa Sorensen-Unruh and Tanya Gupta edited a book on the use of social media to communicate chemistry.[13] The book includes valued chapters ranging from how to incorporate a social media communication plan into a grant proposal,[14] through how to communicate science on social media from the personal experience of a small chemical business owner.[15]

[a] *Dr. R. Ciriminna, Dr. M. Pagliaro*
Istituto per lo Studio dei Materiali Nanostrutturati
CNR
via U. La Malfa 153
90146 Palermo (Italy)
E-mail: rosaria.ciriminna@cnr.it
mario.pagliaro@cnr.it
[b] *Dr. A. Scurria*
AMAP SpA
Impianto Depurazione Acqua Dei Corsari
via Messina Marine 821
90121 Palermo (Italy)

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A 2018 survey of chemistry faculty, staff, and graduate students at four Canada's universities found that "many chemists fail to develop new information seeking behaviors to remain informed and grasp developments outside their narrow field of expertise".[16] Similarly, meta-research carried out in 2021 found that most academics do not use social media. Those who did, actually did it mostly for research and career development reasons, including networking, rather than to support learning and teaching activities, even though an increasing number of academics was found using social media to share their research work with the public.[17]

As put by Amy Mollett and co-authors, today "social media connects with each of the different phases of the research cycle, such as inspiration, collaboration, primary research, dissemination, engagement, and impact".[18] Research chemists interested in learning the technical guidelines on how to effectively use social media may refer to thoughtful studies[19,20] and books.[18,21] Aimed at identifying the main benefits of social media utilization by chemistry scholars with respect to the three main scholarly activities (research, education and societal service),[22] this study offers an updated overview of social media for chemistry scholars. The time and psychological risks of social media utilization, as we suggest in the conclusions, must be managed and new education on purposeful utilization of social media must be planned and delivered.

Results and Discussion

Table 1 lists selected social media platforms along with the current number of active users[23–26] and their main characteristics. As of early 2023, two platforms (Facebook and YouTube) had over 2 billion users.

Table 1. Main features of selected social networks, including academic social networks, and number of active users.

Social media	Number of active users (in billions as of January 2023)	Main features
Facebook	2.95	Social network site where users can post text, links, share photographs and videos. Shared content can be made publicly accessible, or shared only among a select group of people ("friends"). Depending on the selected privacy, users can comment, like, and share posts publicly or with their friends only.
YouTube	2.51	Video-sharing website with high degree of interactivity through its community posts, comments, likes, and shares.
Instagram	1.22	Picture and video-sharing application. Posts can be shared publicly or with preapproved "followers". Mainly mobile-based.
TikTok	1.00	Video-sharing app. Users create and share short-form videos. Mainly mobile-based.
LinkedIn	0.90	Professional social network site. Also offers the possibility to create groups and manage discussion forums.
SnapChat	0.63	Picture and video-sharing app. "Snaps" last for a limited time only. Mainly mobile-based.
Twitter	0.56	Social network site. Each post cannot exceed 280 characters. Users post or reply to texts, images and videos informally called "tweets".
Academia.edu	0.221	Academic social network site.
ResearchGate	0.023	Academic social network site.

Rosaria Ciriminna is a senior research chemist at Palermo's Institute for nanostructured materials of Italy's CNR. Developed in cooperation with over 20 research groups in Italy and abroad, her research encompasses a broad domain going from heterogeneous catalysis for fine chemical manufacturing through the development of natural production extraction processes. Her research achievements are reported in over 270 research papers. Co-author of numerous books, Rosaria often mentors graduate and undergraduate students, and acts as a reviewer on behalf of research agencies and ministries.

Antonino Scurria has carried out several years of research at Palermo's Institute for nanostructured materials. Joint research achievements include the introduction of new micronized cellulose CytroCell and newly developed citrus IntegroPectin-based antimicrobial films. He has published 45 research papers. In 2022, he joined the ranks of Palermo's publicly owned water company.

Mario Pagliaro, Research Director at Italy's CNR, is a chemistry and energy scholar based at the Institute for nanostructured materials. Frequently cited for his excellence in teaching, he has co-authored over 330 research papers and numerous books. The joint achievements of his research team's work span from the new IntegroPectin citrus pectin to the Grafeo-Plad catalyst. Designated Fellow of the Royal Society of Chemistry in 2014, in 2021 he was elected ordinary member of the Academia Europaea.

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Each social media has its own characteristics. For example Twitter, a micro-blogging social media platform, is widely used by researchers to share short messages, photos, and videos, with the ability to link to external websites for more detailed information.

According to meta-research published in 2021,[17] during the five-year period from 2014 to 2019, academics chiefly used Twitter, ResearchGate, Academia.edu and LinkedIn.

ResearchGate and Academia.edu are academic social network sites (ASNS), namely online platforms in which scholars share research papers, ask questions, provide answers, review job offers, etc. They are widely used by scholars including students, early career and precarious academics who find in ASNS a highly visible (the site web pages are very well indexed and readily found by search engines) online space to freely host their online professional identity when their institutions do not provide this for them.[27]

Reviewing research published in peer-reviewed journals between 2014 and 2019 (search based on keywords that included social media academics and academia) Macht and co-workers recently found eight main benefits brought to academics by the use of social media. Ranging from access to more research opportunities to the intrinsic possibility offered by the internet to transcend geographical boundaries, said benefits are listed in Table 2.[17]

In the following, we provide an overview of social media for chemistry scholars aimed at identifying the main benefits of social media utilization by research chemists with respect to the three main scholarly activities: research, education and societal service.[22]

Support to research

As mentioned above, citing Carolyn Bertozzi following on Twitter "what is happening in so many labs, places and fields",[11] the use of social media like Twitter allows scholars to learn about research achievements in their own field. Researchers, indeed, use social media to better disseminate research work by "posting" the news of research achievements (preprints, research articles, books, presentations etc.) on one or more social media platforms. Twitter, in this respect, is particularly effective due to the brevity of message, and the capacity to include images, videos and a link so that interested colleagues "can go through a lot of information at a glance, with the option to dig deeper if they wish".[28]

A small (but growing) minority of chemistry scholars, furthermore, preprint their research.[29,30] These researchers typically post the news of the new preprint in a social network allowing colleagues to learn about new advances several months before they will appear in a peer-reviewed journal.

Research work benefits by its communication on social media also through constructive feedback received on the social platform. In this respect, the effective use of a social media is the opposite of what senior researchers typically do after having opened an account: "I have done this, you should look at it".[31]

As noted by Emily Darling and co-workers, using a social medium to disseminate research findings reported in a new manuscript allows scholars to convey the conclusions of the paper "both more informally and more informatively than a paper's title can",[32] whereas the "post" that is subsequently shared by other social media users will reach a much wider audience than that of a scientific journal (or preprint server), "with relatively little effort on the part of the initial author".[32]

As expected, the use of social media to disseminate research achievements and interact with colleagues from across the world significantly widens collaboration opportunities. Indeed, evidence of scientists using social-networking sites to foster collaboration goes back to the early 2010s.[33]

Finally, the effective use of social media communication possibilities, for example to organize or to follow a scientific conference or a workshop, often saves time and valued financial resources. Twitter, for example, can be used to communicate the main points of a presentation at a scientific conference,[34] whereas some conferences (and particularly seminars) may be held fully online in social media platforms on LinkedIn, Facebook video, and YouTube platforms with synchronous Q&A [Question and Answer] session open to viewers.

For example, since 2015, the Royal Society of Chemistry organizes #RSCPoster on Twitter, a poster conference held each March in which, for 24 h, researchers from around the world freely tweet their poster with a title and two hashtags (#RSCPoster and relevant subject) and thus discuss their work on Twitter as well as on other social media platforms.[35]

In other words, the purposeful use of social media contributes to save (and not to waste) researcher's working time, thereby contributing to improve scholarly research work, that intrinsically requires the ability to focus on a cognitively demanding task without distraction for a prolonged period of time.[36]

Table 2. Benefits of social media usage for academics (Reproduced from Ref. [17], with kind permission).

	Benefit
1	Access to more research opportunities
2	Improved networking and communication with peers and students
3	Increased access to experienced researchers
4	Increased motivation to continue using social media
5	Increased student ratings
6	Increased willingness to publish
7	Supports and facilitates teaching and learning
8	Transcends physical and geographical boundaries

Support to teaching and learning

Social media today are widely used tools in science education. Their use in chemistry education has been very successful in both economically developed[37–39] and developing countries.[40,41]

In 2017, scholars in Singapore reported the "extremely positive" student response to the incorporation of Instagram (a

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photo-sharing social networking application for mobile "smartphones" and other mobile devices) and Snapchat (a photo-messaging application for mobile devices allowing users to send images and videos that disappear after a set amount of time) in the organic synthesis laboratory.[37] Aiming to "encourage peer-learning through social media and let the students chat on the reactions", videos of student laboratory work were recorded by the lecturer and shared on the two platforms. Only the student's hands were filmed, without filming faces or fume hood numbers. Furthermore, the team shared a total of 15 "snaps" in Snapchat (and two compiled videos in Instagram) per day so as to avoid overwhelming students with too many images and videos.

The learning content uploaded was "hugely successful in enabling the students to observe mistakes and improvisations and seek a deeper understanding of the experiments".[37] In full agreement with theory explaining that chemistry is both learned and practiced by visualization,[42] nearly all students were found to be visual learners: out of 93 who responded to the survey, 74 students indicated that they learn best by seeing and visualizing.

Similarly, chemistry, biochemistry, and natural sciences students in the United Kingdom viewing images and videos shared by their instructors on Snapchat reported significantly higher levels of engagement with chemistry (and understanding of how chemistry can be applied to affect their daily lives).[38] In detail, Snapchat was used to share videos and pictures with the 140 students out of 300 who decided to follow the newly created laboratory account. Upon surveying 43% of the participants, 83% responded that using Snapchat was a valuable addition to their learning experience in chemistry.

Rather than reviewing the use of all social media in chemistry education, the key point here has been raised by Fun Man Fung and co-workers in 2017,[37] and again by Tanya Gupta and collaborators in 2019:[8] students today spend a significant amount of time connecting with their peers and friends on social media. Hence, today's chemistry educators need to purposefully use social media, integrating their use in conventional classroom lectures and laboratory courses. However, we agree with Robert Pribush: successful chemistry education continues to rely on instructor knowledge, creativity and ability to establish a strong instructor-student bonding, so that technology will never take the professor out of the process.[43] Even in today's digital era, not only can digital technology not replace the unique role of the professor, but said role expands in guiding students *to avoid* the overuse of social media that distracts students and makes them both unsociable and less focused.[43]

Support to service to society

Aiming to create communities and involve their members in online conversation, social media may vastly benefit societal service scholarly work. Many chemistry scholars are engaged in carrying out public advocacy, government advice, science outreach and public engagement activities.

For example, when writing in reputable online publications for the public sharing their insight and responding to reader comments, scholars benefit their work and their hiring universities through largely increased social visibility, being also frequently approached by journalists with requests for interviews.[44]

By sharing the news of their service to society activities in a social media platform further amplifies said impact, and contributes to involving fellow citizens in public discourse. As early as of 2016, the American Sociological Association suggested standards by which university departments may consider social media activity and other public communication in tenure and promotion decisions by recognizing and rewarding public engagement.[45]

In brief, through social media researchers may easily share their knowledge as a service to society. This is particularly important for chemistry which, regardless of its plentiful benefits to society (not only in terms of new functional substances and materials, but in terms of human lives saved through new chemical substances and processes),[46] has a long way to go to change the public perception of chemistry as the science behind a harmful industry threatening human health and the environment (chemophobia).[47]

For instance, communicating through social media the achievements and innovations brought about by green chemistry with respect both to the production of "chemicals" (the chemical industry products) and the ongoing systematic replacement of hazardous chemicals with intrinsically safe chemical products is a highly effective way to combat the consequences of chemophobia.[48]

In addition, the two-way communication characteristic of social media platforms (using a plain language and not a "myth-busting", ineffective approach),[47] allows to also tackle what Sara Tortorella and co-workers aptly called "the other kind of chemophobia",[47] namely the anxiety generated in lay people by most chemistry school courses.

In other words, chemistry scholars may exemplify to the public how today's chemistry research and education no longer limit their contribution to environmental protection by developing analytical techniques for contaminants, but rather work at preventing pollution (contamination) altogether, shifting their role in protecting the environment from *control* to *prevention*.

In this global effort of co-creation for sustainability in which universities collaborate with government, industry and civil society in jointly developing "social, technical and environmental transformations of a specific geographical areas",[49] chemists working in industry, government and academy may give a uniquely important contribution, made more effective by its communication through social media.

The latter, for example, can be used to promote and communicate innovative courses on solar energy[50] or natural product green extraction[51] jointly developed by research chemists. In brief, when devising societal service initiatives, it is no longer possible to avoid the use of social media currently used by nearly 60% of the world's population.[2]

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Conclusions and Outlook

In summary, the purposeful utilization of social media in the scholarly activity of chemists offers plentiful benefits with respect to each of its three main components: research, education and societal service. Two-way communication channels such social media, however, present two main risks: a time and a psychological risk.[52]

The time risk arises because many people tend to devote too much time to social media becoming unproductive in their work. The psychological risk exists because once someone starts sharing information and interacting with social media users, the social media platform becomes vulnerable to people posting aggressive or culturally and socially insensitive remarks, including claims without merit by people who just want to cause trouble ("trolls").

These risks must be managed. Mitigation of psychological risk requires moderation of content in social media conversations, so that remarks not meeting norms of civil behavior are readily removed and their authors banned. To avoid waste of time, in its turn, the use of social media should be limited to a specific and limited period of time of the workday, avoiding frequent interruptions which are the enemy of productive intellectual work.[53]

Likewise to the uptake of open science tools in scholarly communication,[54] or the use of e-mail in the academy,[55] the purposeful use of social media requires to educate chemistry researchers on their effective utilization, including the ability to teach students *how* to avoid the negative sides of social media. Planning said educational work, instructors may rely on the outcomes of early studies of social media utilization by chemistry scholars.[8,13,37] From collation and curation of social media content,[56] through the use of social media to engage students and improve chemistry learning,[9,37–41] this will avoid to repeat mistakes done in the early utilization of these powerful communication tools, opting instead for the aforementioned purposeful utilization that has shown to afford lasting benefits in education, research and service to society.

Competing interest

The Authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Conflict of Interests

The authors declare no conflict of interest.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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