

Fighting fake science: the key role of scientists

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“In some periods, interviews with well known personalities on current problems were particularly popular. ... Noted chemists or piano virtuosos would be queried about politics, for example, or popular actors, dancers, gymnasts, aviators, or even poets would be drawn out on the benefits and drawbacks of being a bachelor, or on the presumptive causes of financial crises, and so on. All that mattered in these pieces was to link a well-known name with a subject of interest. ... If a famous painting changed owners, if a precious manuscript was sold at auction, if an old palace burned down, if the bearer of an aristocratic name was involved in a scandal, the readers of many thousands of feature articles at once learned the facts. What is more, on that same day or by the next day at the latest they received an additional dose of anecdotal, historical, psychological, erotic, and other stuff on the catchword of the moment. A torrent of zealous scribbling poured out over every ephemeral incident, and in quality, assortment, and phraseology all this material bore the mark of mass goods rapidly and irresponsibly turned out.”

Hermann Hesse, *The Glass Bead Game*, 1943 [1]

The introductory citation from *Glass Bead Game*, a masterpiece of world literature by Herman Hesse originally published in 1943, was a dystopian view of imagined future, yet, from today’s perspective, the description appears eerily prescient. The excerpt could easily be misunderstood as describing the present times where the surplus of information and opinions is publicly shared on any subject by anyone. The advance of information technologies, which rapidly accelerated in the second half of the 20th century, benefited the world enormously by providing means to easily access and exchange information. However, Internet-driven Information Age also promoted creation and spread of incorrect and even malevolent information. Although, misrepresenting the truth is nothing new in human history, the scale and speed of transmission afforded by the World Wide Web, furthered by incitement to create ‘click-bait’ content, led to wide-spread phenomena of ‘fake news’ and even ‘fake science’.

The problem with unverified theories falsely presented as scientific is that readership believes them to be true, which can produce harmful effects at all societal levels. For example, as a consequence of an erroneous report connecting autism and the MMR vaccine, Europe had seen an increase in measles infection in 2018 and rise in ‘vaccine hesitancy’ [2]. Other examples include denial of anthropogenic influences on climate change and minimizing health risks of smoking [2]. The COVID-19 pandemic in 2020 provided a fertile ground for the spread of fake news and fake science that contributed to public confusion and provoked further proliferation of conspiracy theories. Some of these ‘theories’ deny existence of the pandemic and its associated health risks, reject scientifically verified statistics and propagate false remedies (e.g. [3]). These false reports can potentially impact on public policy and health outcomes. This situation clearly

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highlights the need for scientists to take a more prominent role in fighting fake science, by ensuring quality publications, educating the public, and engaging in public debate.

Science can be defined as a pursuit of truth and knowledge by a set of methods based on evidence, to describe and interpret the natural and social world [4,5]. Scientific methods include systematic observation, measurements and experiments, formulation and testing of hypotheses, critical analysis, and verification by critical scrutiny, result replication, peer review and assessment [5,6]. The scientific method is actually what separates scientific results from opinions, beliefs, and assumptions. Application of scientific method requires investment of time and resources, and participation of scientific community to review and verify findings and conduct studies to confirm credibility of the results. Thus, what is printed in scientific publications is taken as de-facto scientific truth, presumed to have been through the rigorous verification process. Correspondingly, to dispute a single erroneous publication, multiple independent studies are required. For example, to expose a published paper, which claimed that blood cells of patients with chronic fatigue syndrome were infected with the retrovirus XMRV as inaccurate, publication of numerous independently conducted studies carried out by reputable research groups was required [7]. Scientists are trained to remain truthful and comply with strict scientific and ethical standards, including conscientiousness, accountability, integrity, open collaboration and transparency [8]. True scientists would never be involved in data fabrication, misrepresentation, and plagiarism but the cases of research misconduct in the last several decades have damaged the public trust in the “very fabric of scientific inquiry - scientific integrity” (Jones, 2007, p. 27 [9]). Regrettably, and unbelievably, the person responsible for the fraudulent claim regarding the retrovirus XMRV is still active and currently spreading unverified information on COVID-19 [7]. Thus, it is of utmost importance that scientists ensure that only scientifically verified results are published in the first place. When communicating scientific results, scientific procedures should always be presented clearly and precisely, ensuring reproducibility of results, an approach which this publication, **Hemijaska Industrija**, espouses. As an open access journal with mandatory peer-review, data accessibility and clarity, with particular emphasis on experimental techniques and protocols assuring possibilities to replicate the published studies, **Hemijaska Industrija** aims to maintain the highest standards of scientific inquiry and reporting and contribute to better understanding of science and scientific method by its audience.

Drowning under the noise of conspiracy theorists, pseudoscientists, and various activists, it often seems that the voice of scientists is hardly heard or is misunderstood by the public. Scientists confine their statements to scientifically proven facts as honesty is one of their main virtues [8]. In today’s cacophony of voices, scientists need to adopt an active role within the domain of science itself not only by upholding the highest ethical standards, transparency, objectivity, and reproducibility in their own work [2,10], but also towards the society at large by effectively communicating scientific methods and findings, thus increasing the scientific literacy of the public. In parallel, scientists should instantly and convincingly react to any false information appearing in media or presented by public figures [2]. Although technological advancements provide possibilities to automatically discover plagiarism, false claims, and fake news (e.g. [11]) without capabilities for critical thinking and analysis, a person remains a passive receiver and, potentially, a purveyor of the served information, susceptible to different kinds of manipulation. Scientific education in schools certainly provides a basis for understanding scientific results and concepts with the further aim on enhancing abilities for critical thinking and analysis in order to equip youth with skills to evaluate information and its veracity [2]. Still, the broader public should continuously be engaged with meaningful science communication with the main goal of improving the population’s confidence in science, and development of social acceptance and epistemic and moral trust [12]. With regard to increasing scientific literacy and possibly abilities for critical analysis, the model of public participation seems particularly attractive [12]. For example, citizen science projects involve a large number of participants that together with professional scientists collect, submit or analyze large quantities of data and thus can lead to better understanding of science and the scientific research process and methodology [13].

Performing good scientific research is a highly creative human activity that brings immense benefits through discovery and innovation. And although practicing strict scientific methods and upholding highest scientific ethics is demanding, the very rigor of scientific inquiry provides assurance to research practitioners and societies they practice in. Scientific method offers guiderails for engaging scientific curiosity, charting paths for search for answers and provides

basis for scrutinizing findings. Thus, the joys of scientific inquiry and discoveries can be shared by the whole society. In today's climate of information overload, propagation of fake information and proliferation of conspiracy theories, the scientists and the societies that embrace them, have mutual responsibility to instigate and cultivate the scientific method and critical inquiry. The scientific community must strive to support the society through consumable presentation of scientific findings, ongoing public education, and willingness to engage in public debate.

Suzbijanje lažne nauke: ključna uloga naučnika

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REČ UREDNIKA

Ključne reči: naučna komunikacija; teorija zavere; naučni integritet; etika nauke; naučni metod.

“Povremeno su naročito bili omiljeni intervjui poznatih ličnosti o dnevnim pitanjima...; u intervjuiima se na primer čuveni hemičar ili virtuoz na klaviru, omiljeni gluac, plesač, gimnastičar, letač ili čak pesnik izjašnjavao o koristi i nedostacima statusa neženje, o mogućim uzrocima finansijske krize i tako dalje. Jedino važno pritom bilo je spojiti poznato ime s nekom dnevno aktuelnom temom. ... Kad bi neka čuvena umetnička slika promenila vlasnika, ili kad bi neki vredni rukopis bio prodat na licitaciji, kad bi u požaru izgoreo neki stari zamak, kad bi pripadnik stare plemićke loze bio umešan u neki skandal - čitaoci bi u hiljadama feljtona saznali ne samo ove činjenice, nego bi istoga ili sledećeg dana dobili još mnoštvo anegdotskog, istorijskog, psihološkog, erotskog i drugog materijala na aktuelnu temu; o svakom događaju dana prolila bi se prava bujica žustrog piskaranja, a stavovi, mišljenja i formulacije svih ovih izveštavanja nosili su, bez izuzetka, pečat brze i neodgovorno proizvedene robe za široku potrošnju.”

Herman Hese, *Igra staklenih perli*, 1943 [14]

Uvodni citat iz remek-dela svetske književnosti *“Igra staklenih perli”* Hermana Hesea prvi put objavljenog 1943. godine, predstavlja distopijsku viziju zamišljene budućnosti ali iz današnje perspektive, opis izgleda zastrašujuće dalekovidan. Citat bi se lako mogao pogrešno shvatiti kao opis sadašnjeg vremena u kome se obilje informacija i mišljenja bilo koga o bilo čemu javno iznosi.

Napredak informacionih tehnologija koji se naročito ubrzao u drugoj polovini 20. veka je doneo svetu ogromnu korist u vidu mogućnosti jednostavnog pristupa i razmene informacija. Međutim, Informatička era pospešena internetom je takođe podstakla i pojavu i širenje netačnih pa čak i zlonamernih informacija. Iako netačno prikazivanje činjenica nije ništa novo u ljudskoj istoriji, obim i brzina prenošenja koju je omogućila svetska komunikaciona mreža (engl. *World Wide Web*) dopunjena mogućnošću postavljanja sadržaja pod manipulativnim naslovima koji služe kao “mamci za klikove” (engl. *click-bait*) su doveli do širenja fenomena “lažnih vesti” i čak “lažne nauke”. Problem sa nepotvrđenim teorijama koje se lažno predstavljaju kao naučne je u tome što čitaoci veruju u istinitost tih navoda, što može da dovede do štetnih posledica na svim društvenim nivoima. Kao primer može se navesti porast obolelih od malih boginja u Evropi 2018. godine i “neodlučnosti o vakcinisanju” usled netačnog izveštaja koji je povezo autizam i MMR vakcinu [2]. Drugi primeri uključuju poricanje antropogenih uticaja na klimatske promene i umanjivanje činjenica o riziku po zdravlje i štetnosti pušenja [2]. Trenutno, pandemija COVID-19 predstavlja plodno tle za ekspanziju lažnih vesti i lažne nauke što je doprinelo konfuziji u društvu i dalje izazvalo mnogobrojne teorije zavere. Neke od tih tzv. teorija poriču postojanje pandemije i povezanih rizika po zdravlje, odbacuju naučno potvrđene statističke podatke i promovišu lažne lekove (npr. [3]). Takvi lažni izveštaji mogu potencijalno da utiču na javne politike i zdravstveni ishod. Ova situacija jasno ističe potrebu da se naučnici značajnije uključe u borbu protiv lažne nauke i to, obezbeđivanjem kvaliteta naučnih publikacija, podučavanjem javnosti i učešćem u javnim debatama.

Nauka se može definisati kao potraga za istinom i znanjem primenom serije metoda baziranih na dokazima, radi opisivanja i interpretacije prirodnih i društvenih pojava [4,5]. Naučne metode uključuju sistematično posmatranje, merenje i izvođenje eksperimenata, formulisanje i testiranje hipoteza, kritičku analizu i potvrdu rezultata kritičkim preispitivanjem, ponavljanjem rezultata i stručnom recenzijom i procenom [5,6]. Zapravo, naučni metod predstavlja osnovnu razliku koja razdvaja naučne rezultate od samo mišljenja, verovanja i pretpostavki. Primena naučne metodologije zahteva vreme i resurse, kao i učešće naučne zajednice radi pregleda rezultata i izvođenja dodatnih

istraživanja da bi se potvrdila verodostojnost dobijenih nalaza. Stoga, objavljeni radovi u naučnim publikacijama se prihvataju kao defakto naučno istiniti, pretpostavljajući da su bili podvrgnuti rigoroznom procesu verifikacije. Na taj način, za opovrgavanje samo jednog pogrešnog, objavljenog rada, potrebno je izvođenje višestrukih nezavisnih studija. Na primer, za otkrivanje da je naučni rad u kome je izneta tvrdnja da su ćelije krvi pacijenata sa sindromom hroničnog umora inficirane retrovirusom XMRV, bio netačan, bilo je potrebno objavljivanje brojnih nezavisno izvedenih studija priznatih istraživačkih grupa [7]. Naučnici su trenirani da se pridržavaju istine i striktnih naučnih i etičkih standarda koji uključuju savestnost, odgovornost, integritet, otvorenu saradnju i transparentnost [8]. Istinski naučnici stoga nikada ne bi učestvovali u fabrikovanju podataka, lažnom predstavljanju nalaza i plagijarizmu ali su slučajevi nedoličnog ponašanja u nauci u poslednjih nekoliko decenija oštetili poverenje društva u "samu materiju naučnog istraživanja – naučni integritet" (Jones, 2007, p. 27 [9]). Nažalost i neočekivano, osoba odgovorna za obmanu u vezi retrovirusa XMRV je i dalje aktivna i trenutno širi neproverene informacije o bolesti COVID-19 [7].

Prema tome, od najvećeg je značaja da naučnici na prvom mestu osiguraju publikovanje samo naučno potvrđenih rezultata. Pri objavljivanju naučnih rezultata, naučne procedure moraju biti jasno i precizno prikazane radi omogućavanja ponovljivosti rezultata, i to je pristup koji neguje časopis **Hemijska industrija**. Kao časopis sa otvorenim pristupom, obaveznom naučnom recenzijom, uz pristupačnost i razumljivost podataka, i sa posebnim naglaskom na eksperimentalne tehnike i procedure obezbeđujući mogućnost ponavljanja objavljenih studija, **Hemijska industrija** teži da održi najviše standarde naučnih istraživanja i izveštavanja i da doprinese boljem razumevanju nauke i naučnog metoda.

Pod udarom buke teoretičara zavere, pseudonaučnika i različitih aktivista, često se čini da je glas naučnika jedva čujan ili je pogrešno shvaćen u društvu. Naučnici ograničavaju svoje izjave samo na naučno dokazane činjenice jer je poštenje jedna od njihovih osnovnih vrlina [8]. U današnjoj kakofoniji glasova, naučnici treba da preuzmu aktivnu ulogu u okviru domena same nauke, ne samo održavajući najviše etičke standarde, transparentnost, objektivnost i ponovljivost u svom radu [2,10], već i šire u društvu razumljivim i verodostojnim prikazivanjem naučnih metoda i rezultata doprinoseći na taj način podizanju naučne pismenosti populacije. Istovremeno, naučnici treba momentalno i ubedljivo da reaguju na svaku netačnu informaciju u medijima ili koju je iznela neka javna ličnost [2]. Iako tehnološki napredak omogućava automatsko detektovanje plagijarizma, neistinitih navoda i lažnih vesti (npr. [11]), bez sposobnosti kritičkog mišljenja i analize, osoba ostaje pasivni primalac i, verovatno, i prenosilac servirane informacije, podložna različitim vrstama manipulacije. Naučno obrazovanje u školama svakako pruža osnovu za razumevanje naučnih rezultata i koncepcija, pri čemu je poboljšanje sposobnosti za kritičko mišljenje i analizu dodatni cilj da bi omladina stekla veštinu da proceni informaciju i njenu verodostojnost [2]. Ipak, i šira javnost treba da bude konstantno uključena u razumljivu naučnu komunikaciju uz glavni cilj povećanje poverenja u nauku, u epistemološkom i moralnom smislu, i razvoj društvenog prihvatanja [12]. Model društvenog uključivanja u naučna istraživanja izgleda naročito atraktivan za povećanje naučne pismenosti i, moguće, i sposobnosti za kritičko mišljenje [12]. Na primer projekti "stanovnici u nauci" (engl. "citizen science") uključuju veliki broj učesnika koji zajedno sa profesionalnim naučnicima sakupljaju, podnose ili analiziraju velike količine podataka što može da dovede do boljeg opšteg razumevanja nauke i procesa i metodologije naučnog istraživanja [13].

Izvođenje kvalitetnih naučnih istraživanja je veoma kreativna ljudska aktivnost koja naučnim otkrićima i inovacijama donosi ogromne koristi društvu. I iako je sprovođenje striktnih naučnih metoda i pridržavanje najviših naučnih etičkih principa zahtevno, sama rigoroznost naučnih istraživanja omogućava sigurnost istraživačima i društvu u kome oni rade. Naučni metod pruža smernice za angažovanje naučne radoznalosti i potrage za odgovorima, kao i osnovu za analizu dobijenih rezultata. Prema tome, zadovoljstvo i radost koje donose naučna ispitivanja i otkrića se mogu podeliti sa celim društvom. U današnjoj klimi pretrpanosti informacijama, proturanja lažnih vesti i umnožavanja teorija zavere, naučnici i društvo imaju uzajamnu odgovornost da neguju i stimulišu naučni metod i kritičku analizu. Naučna zajednica mora da nastoji da podrži društvo razumljivim prikazom naučnih nalaza, neprekidnim obrazovanjem javnosti i voljom da učestvuje u javnoj debati.

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