C O P E
Member since 2019
JM14482

Prace z warsztatu

Aneta Krzewińska*
Małgorzata Dzimińska*
Izabela Warwas*

How Understanding the Nature of Science Supports Lifelong Learning

Abstract

This study examines Polish citizens' understanding of the Nature of Science (NoS) (McComas 2020) through public consultations on science communication in four areas: climate change, GMOs, vaccinations, and alternative medicine. Qualitative analysis of group discussions revealed that while all NoS elements were addressed, tools, processes, and products of science were most frequently referenced, with human elements and limitations mentioned less often. NoS principles were most evident among participants with higher education. The authors suggest using these insights as a litmus test for Polish citizens' scientific literacy and advocate for professional science communication that goes beyond reporting findings to include explanations of scientific processes. This approach, they argue, can effectively support citizens' lifelong learning.

Keywords: nature of science, scientific literacy, science communication, public consultations, lifelong learning.

Jak zrozumienie natury nauki wspiera uczenie się przez całe życie

Abstrakt

Niniejsze badanie analizuje rozumienie przez polskich obywateli natury nauki (NoS) (McComas 2020) poprzez konsultacje społeczne dotyczące komunikacji naukowej w czterech obszarach: zmian klimatu, GMO, szczepień i medycyny alter-

Artykuł otrzymano: 5.02.2025; akceptacja: 17.07.2025.
* University of Lodz.

https://doi.org/10.18778/2450-4491.21.06

natywnej. Jakościowa analiza dyskusji grupowych wykazała, że chociaż poruszono wszystkie elementy NoS, najczęściej wspominano o narzędziach, procesach i produktach nauki, a rzadziej o elementach ludzkich i ograniczeniach. Zasady NoS były najbardziej widoczne wśród uczestników z wyższym wykształceniem. Autorzy sugerują wykorzystanie tych spostrzeżeń jako papierka lakmusowego dla umiejętności naukowych Polaków i opowiadają się za profesjonalną komunikacją naukową, która wykracza poza raportowanie wyników i obejmuje wyjaśnienia procesów naukowych. Argumentują, że takie podejście może skutecznie wspierać uczenie się obywateli przez całe życie.

Słowa kluczowe: natura nauki, kompetencje naukowe, komunikacja naukowa, konsultacje społeczne, uczenie się przez całe życie.

Introduction

In this qualitative study, the understanding of a hundred ordinary Polish citizens, gathered during a public consultation on science communication in four areas – climate change, genetically modified organisms (GMO), vaccinations, and alternative medicine (Krzewińska et. al. 2021) – were explored to determine if and how their views reflect their understanding of the Nature of Science (NoS). McComas et al. (2002a: 4) define NoS as "a rich description of what science is, how it works, how scientists operate as a social group, and how society itself both directs and reacts to scientific endeavors." In this study, the authors examine citizens' views through the lens of NoS's three key categories: tools, processes, and products of science; human elements of science; and the limitations of science (McComas 2020). The goal is to determine how well participants understand and value science as a dynamic and evolving process (McComas et al. 2002b).

Why is this topic important? Numerous studies demonstrate that an understanding of NoS is closely linked to people's everyday behaviors and attitudes. For example, Weisberg et al. (2021) confirmed that enhancing people's knowledge of how science works can help reduce resistance to scientific claims, regardless of identity factors such as political or religious beliefs. Similarly, Lombrozo et al. (2008) and Nelson et al. (2019) highlighted the importance of understanding NoS principles for better acceptance and comprehension of evolution. McPhetres et al. (2019) found that increased scientific knowledge leads to more positive attitudes toward genetically modified foods, while Ranney and Clark (2016) demonstrated that scientific information can significantly shift people's attitudes toward climate change.

However, researchers also point out that there is often a disconnect between possessing theoretical knowledge and the ability to apply it effectively to real-world challenges (Day and Goldstone 2012). This observation highlights the concept of scientific literacy (SL), which encompasses the ability to use scientific knowledge and principles to understand one's environment and test hypotheses (World Economic Forum 2015). This dimension of SL builds on the three components defined by Miller (1992): a vocabulary of scientific terms and concepts, an understanding of the process of science, and an awareness of the impact of science and technology on individuals and society.

In this context, the concept of lifelong learning (LLL) also emerges as a critical factor in bridging the gap between possessing knowledge and applying it in real-life situations (OECD 2021). LLL is a multidimensional phenomenon with socio-cultural, economic, and – above all – political implications (Malewski 2013). It can be analyzed from three perspectives: micro, meso, and macro. The micro perspective focuses on individual learning and development. The meso perspective examines institutional strategies and frameworks, while the macro perspective considers international, national, political, and legal contexts (Muszyński 2023). For the purpose of contextualizing the understanding of NoS – the focus of this paper – the LLL concept is viewed from the micro perspective. It is defined as a continuous process of acquiring knowledge, skills, and competencies throughout one's life to adapt to the evolving demands of globalization, digitalization, and increasing longevity. This process encompasses formal education, which refers to structured programs such as degrees or certifications; non-formal education, which includes skill-focused courses outside traditional academic settings; and informal learning, which involves experiential knowledge gained through daily activities, work, or community engagement. Individuals who consistently seek, evaluate, and integrate new information into their understanding are better equipped to make informed decisions in complex, real-world scenarios, remain competitive in the workforce, foster personal and social growth, and contribute actively to society (Laal, Salamati 2012). Lifelong learning not only updates existing knowledge or develops new skills but also fosters a critical and informed perception of reality. Moreover, it brings the joy of better understanding life through the lens of one's own experiences (Adamczyk 2022).

The results of this study provide insights into Polish citizens' understanding of NoS and serve as a basis for forming hypotheses about their scientific literacy skills. The analysis of discussions on science communication across four socially significant topics highlights its potential to enhance scientific literacy and support lifelong learning. This can be achieved not only by sharing research findings but also by illustrating the process of scientific inquiry. Effective science communication creates opportunities to foster scientific literacy and critical thinking, both through formal education and through informal and non-formal learning pathways integral to lifelong learning.

Existing literature on NoS often explores how it is perceived by scientists (Schwartz, Lederman 2008), teachers (Dorsah 2020), or students (Gyllenpalm et al. 2022). In this study, we aim to complement these perspectives by investigating how citizens operationalize the concept of NoS during discussions on science communication. Their revealed understanding of NoS forms the basis for discussions and recommendations related to promoting science communication and developing citizens' scientific literacy as tools for supporting lifelong learning and societal engagement.

Theoretical background

The theoretical perspective that was chosen for interpreting the collected material was McComas' approach (McComas 2020), because it clearly organizes key elements of the nature of science relevant to our study. McComas elaborated on key elements of NoS and grouped them into three domains: tools and processes of science, human elements of science, and science limitations.

Under the *Tools, processes and products of science* domain McComas (2020) outlined key principles: evidence is vital in science; laws and theories are distinct but related, and shared methods include induction, deduction, inference, inquiry and argumentation, etc., but no universal stepwise method exists. Science relies on empirical evidence, which, while crucial for knowledge generation, requires careful analysis for valid conclusions. McComas (2020) explains that communicating not only research findings, but also scientific methodology offers significant benefits. Understanding how science operates helps the public evaluate conflicting scientific claims, recognize its inherent uncertainties, and appreciate the evolving nature of knowledge (Yearley 1994). Moreover, McComas highlights that the "knowledge of the nature of science assists students in learning science content" (McComas 2002b: 11).

Additionally, public awareness of scientific processes fosters discernment in distinguishing legitimate scientific discussions and prevents disillusionment with changing conclusions. Finally, speaking about the results without explaining the path to arriving at them is incomplete. Similarly, informing only about research procedures without discussing the results sounds abstract. Therefore, a skillfully prepared and curated information encompassing both aforementioned aspects is perceived as necessary in the process of science communication, thus helping also to enhance people's understanding of NoS and building their scientific literacy. Shapin (1992) stresses the importance of explaining not just what scientists know, but how they arrive at their conclusions:

> Another aspect of public education tends to be neglected [...] a commitment to tell the public how, with what confidence, and on what bases scientists come to know what they do. This can be achieved by telling people what science is like in the making (Shapin 1992: 28).

Under the *Human elements of science* domain McComas (2020) identifies the following key principles: creativity is integral to science; subjectivity and bias are inevitable; and science and society influence each other. These highlight science as a human endeavor, with both strengths and limitations. Creativity differentiates scientists who make breakthroughs from those who do not. It drives bold hypotheses, innovative research, and the exploration of new frontiers. However, complete objectivity is unattainable (Kuhn 1996), as scientists' beliefs, training, and experiences shape how they interpret data (Lederman, Abd-El-Khalick 1998). Science is inherently collective, relying on trust and collaboration, where competent scientists may still reach differing conclusions (Shapin 1992). Modern science is also a team effort, with researchers collaborating to tackle complex problems beyond individual intellectual, financial, or organizational capacities (McComas et al. 2002a). Moreover, science is deeply embedded in and shaped by society and culture – just as it, in turn, influences them (Matthews 2002; Sullenger, Turner 2002).

Under the domain of *science and its limitations* McComas (2020) outlines three key principles: science is distinct from engineering and technology; science is tentative, durable, and self-correcting; science has limits. He stresses a common misconception that science, engineering, and technology are interchangeable and explains that unlike engineering and technology, which are inherently utilitarian, science seeks knowledge for its own sake. Applied science, in contrast, translates discoveries into practical applications (McComas et al. 2002a). Science is also dynamic, adapting to new discoveries rather than adhering to fixed dogma. It aligns with Shapin's (1992) view that scientific judgment is contingent and revisable, meaning today's truths may be reconsidered tomorrow. Recognizing science's limitations is equally important. Since no omniscient entity confirms absolute truth, science strives to approximate reality but never reaches a final, unquestionable answer (McComas et al. 2002a). McComas (2020) advocates presenting science holistically, acknowledging both its strengths and limitations.

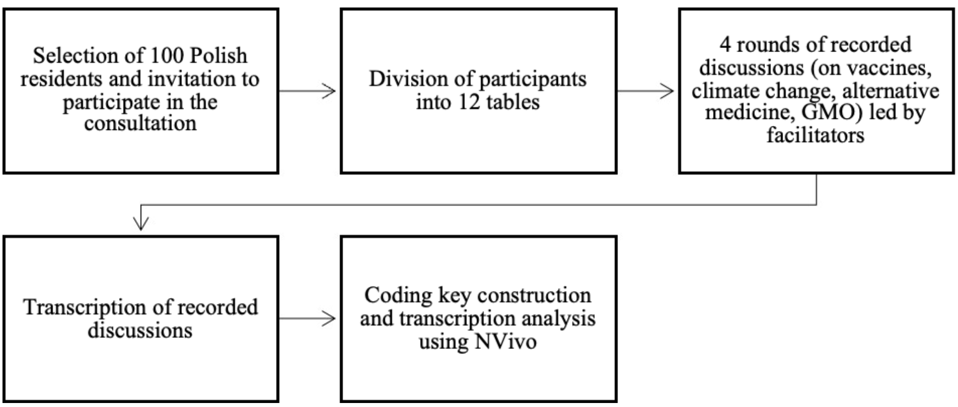
Methodology

This study is guided by the following research questions:

- RQ1: What is the Polish citizens' understanding of NoS key elements as expressed in discussions on science communication?
- RQ2: What approach can be recommended to enhance science communication based on the insights gained from this qualitative study?

Research material collected within the framework of the CONCISE project was used to address the inquiries. CONCISE (2018–2021) was a EU-funded project under Horizon 2020 that focused on Europeans' perceptions of science. Data was collected during custom-designed public consultations on science communication in five countries: Poland, Spain, Italy, Portugal and Slovakia. This article only presents materials from Poland. The decision to focus on Poland is motivated by the desire to explore the perception of NoS in a country that, despite being part of the European Research Area, exhibits significantly lower levels of science communication activity than Germany, Italy, Spain, or Portugal. The project used the World Wide Views (WWV) method as its core methodological approach, adapted to the unique characteristics of research on science communication (Llorente et al. 2022). The WWV method was used for the first time by the Danish Technology Council in 2009 to debate global warming (see: WWV on Global Warming nd.). The aim of the WWV method is to give voice to marginalized people and ordinary citizens, as the opinions of decision-makers, government representatives, major companies, and influential groups tend to receive more attention. The WWV method has also been used for many other debates (e.g. Blue, Medlock 2014; Rask, Worthington 2017; Raney, Clark 2016). A hundred citizens are selected to mirror the region's diversity. Participants are invited to the venue for discussion. At the start of the program, the participants are given a summary of the key issues. Then, they are put into smaller groups for discussion. These discussions are conducted in rounds, lasting 90 minutes maximum. At the end, participants are invited to respond to questions in survey questionnaires, the results of which are published for interested individuals. The use of WWV in multiple locations enables the unification of the entire procedure and facilitates the comparison of results. This allows for the examination of both quantitative and qualitative data in a comparative context. This paper focuses on data collected on September 21, 2019 during Polish public consultations in Lodz. Figure 1 illustrates the subsequent steps in the organization of the consultations.

Figure 1. The steps in organizing public consultations in Poland



Source: own elaboration.

In the context of the CONCISE project, the participants were selected to represent the key socio-demographic characteristics of the population sample. This approach aimed to foster inclusivity. A concerted effort was made to invite a wide variety of participants, and the distribution of their characteristics is presented in Table 1.

Table 1. Distribution of characteristics of the participants (N=100)

Parameter	Range	Value
Gender	Female	63
	Male	37
Age	18–34	30
	35–49	25
	50–64	26
	65+	19
Education	Primary	8
	Secondary	44
	University	48
Place of residence	Country	20
	City	80
Disability		2
Minority status		2

Source: own elaboration.

The participants were divided into 12 groups, with consideration given to ensuring that each group included participants of a similar age and educational level. This was intended to promote group discussion and shared experiences. The meeting was structured into four discussion rounds on different topics: vaccines, climate change, alternative medicine and genetically modified foods. Each round was conducted by experienced facilitators. Participants initiated the session by listing the sources they used to gain scientific knowledge on specific subjects, followed by self-assessing the reliability of these sources. The final part of each round was a presentation of optimal ways to share subject matter with a general audience. All group discussions were documented with the consent of the participants. The recordings lasted 96 hours and were transcribed. The material was then analyzed using NVivo 12 software.

The results

Tools, processes, and products of science

The study participants strongly emphasized that scientific research is conducted in a rigorous manner and that there are certain rules of conduct that scientists have to follow which determine the scope of methodology used in a given study. The most frequently indicated scientific method was an experiment, because according to participants its procedure enables the formulation of truly scientific conclusions, e.g.:

> science also stems from experiments, that's what it's all about, it's an important source of science, yes, but scientific experiments conducted in a rigorous manner

> […] scientific research, among other things, is based on the fact that there is a methodology adopted for it, on the basis of which […] we can draw certain conclusions [F, 35–44, U][1].

The participants noted that scientific research follows a specific procedure, has its own methodology, requires a scheme of conduct. It is of the utmost importance to exercise control over the individual elements of the research procedure when conducting such an experiment. It can therefore be posited that participants equated the terms 'experiment' and 'scientific procedure.' This is also reflected in the statements referring to specific examples in which participants presented a research procedure, for example, in medical research related to drug testing. Therefore, study participants provided a number of examples to prove their understanding of the importance of research methodology, tools and procedures. With reference to the laboratory tests during clinical trials, they stressed that substance testing is a very long and arduous procedure that results in only a few substances being able to become medicines, e.g.

> statistically, twenty per cent of the drugs tested only make it to the end. ...we test about a hundred percent of different substances of which only twenty will realistically be drugs [F, 25–34, U].

The participants argue that these strict rules determine all or most of the activities performed by researchers in the course of their research work. More precisely, the participants referred to the rules related to the use of tools or performing technical activities as well as to the ones governing the conduct of researchers towards research subjects, e.g.: "...all it takes is the procedure, the rules, taking care of people" [F, 25–34, U], which may link to the ethical dimension of scientific literacy. This is a crucial contribution to the field, as it demonstrates that those engaged in the consultation were cognizant of the constraints inherent to scientific experimentation. Indeed, they emphasized the necessity of providing appropriate care for those engaged in scientific research. According to the participants, following scientific rules in a strict manner enables one to control the whole process of the study and thus to obtain reliable results, recalling the practical dimension of scientific literacy e.g.: "immediately the person found out that: and yet this drug is controlled. Laboratory tests carried out […] this medicine is suitable" [F, 65+, P].

In the statements of the participants, we can encounter terms that directly refer to research methodology. For example, the participants referred to "scientific experiments," "research procedures," "scientific methods," "experiments, laboratory tests." It should be noted that most often some general terms referring to the conduct of research are cited rather than specific research methods. The participants identified the need to verify research findings using a control group: "this scientific research confirms that the control group and the research group worked, [the results – note] […] it is accepted then" [M, 25–34, U], as part of the research procedure. What can be

[1] The following abbreviations have been used: F=female, M=male, P=primary school, S=secondary education, U=university degree and 18–24, 25–34, 35–44, 45–54, 55–64, 65+ to indicate the age range of a participant.

observed here is an awareness of the process of scientific inquiry and the significance of evidence as well as the ability to correctly apply specialized terminology.

The participants also argue that the use of scientific procedures enables one to distinguish between science and pseudoscience. This distinction is based on the presence or absence of rigorous research procedures, which are considered a defining feature of the former and lacking in the latter. For example, the absence of proper methodology – whether in conducting research or in drawing conclusions from it – is what ultimately renders the views of anti-vaccinationists unscientific, as illustrated by the following:

> I will not waste my life and so many hours on anti-vaccinationists who give arguments that are: either unreliable, or have a bad methodology, or when you read it, there is a different conclusion than they draw [F, 25–34, U].

Human elements of science

According to the participants, the need for a control of the research process pertains not only to basic research, but it extends to the entire science-making process, including checking the so-called "entrenchment", i.e., the rooting of a given phenomenon in the literature, the relevance of other studies, e.g.:

> You look at who has published what, how many articles there are in general that are supported by the position of the university or research center, that have been replicated by someone else [F, 35–44, S].

This illustrates the necessity for continuity in scientific work and a certain tradition in the conduct of research. The participants note the continuity of the process of scientific development and in this context also the need for researchers to be capable of admitting a mistake or going down a blind alley. This stems from an awareness that a researcher cannot achieve complete objectivity.

At the same time, the publication of research results in journals with an international reach makes it possible to exchange knowledge relatively quickly and there are no obstacles in following the latest research reports and research results from countries on other continents. It is believed that institutional support, equipment and tools necessary for research, including funding for access to databases, library resources or researchers' mobility, are very useful in this process. It is only through awareness of current scientific developments, including the latest discoveries and ongoing research, that researchers can actively engage in scientific discourse.

Conducting public disputes and discussions on research findings, constructive criticism, raising doubts or even objections made by scientists is a natural process, according to the participants: "the researcher or scientist […] gives his opinion […] makes his objections" [M, 65+, P] and it is inherent in scientific progress. This happens in a process Durant (1994) describes as collaborative, but also competitive. It shows not only that science is a creative endeavor, but that subjectivity and bias are present in science. It is not simply collaboration between researchers that facilitates new discoveries; competition between groups of researchers also plays a role in this process.

The consultation's participants underscored the significance of critical thinking for the advancement of scientific knowledge. Furthermore, it was highlighted that this critical thinking is not only crucial during the creation stage, but also during the reception of scientific content. Finally, the participants recognize that it would be desirable that the knowledge of science-making be conveyed as early as in schools rather than only at a further stage of education, that is, at universities. This applies among others to teaching critical thinking: "it would be useful for children to be taught the scientific method of critical thinking at school, I think it would also be extremely important" [M, 25–34, U].

Scientific inquiry was seen as a core aspect of a researcher's role in society, as reflected in statements such as: „they can do research, they can test, they can refute, they can confirm, they cannot deny, they have to publish, this is what scientists can do" [M, 18–24, S].

Participants acknowledged that researchers must not only confirm or falsify hypotheses but also actively publish their findings. They expected scientists to engage in both academic communication (through specialized journals) and public outreach (via popular science articles). Moreover, respondents believed researchers should take an active stance in defending scientific knowledge rather than waiting to be consulted, emphasizing their role in shaping discourse: „Definitely, reaction should follow when the current knowledge is challenged" [M, 25–34, U].

At the same time, scientists were seen as key figures in making complex issues accessible to the public: „And here is the role of scientists – to explain in an easy-to-understand way what the opportunities and threats are" [M, 45–54, U].

Science limitations

Interesting arguments supporting the validity of distinguishing engineering and technology from science were made during the discussion on observable and not directly observable phenomena. The participants mentioned certain natural phenomena (e.g., the lack of water) that they can observe themselves and for which there is no need to refer to scientific reports. They contrasted these with natural phenomena that happen at the microscopic level, where they have to rely on detailed and sound knowledge and evidence provided by scientists, e.g.:

> There is a lack of water in the Sulejów Reservoir, it is actually lacking. Nobody has to confirm this to me experimentally. However, when it comes to various chemical reactions, […] I have to believe the scientists that this has actually been proven in some way [M, 25–34, U].

The participants also spoke about a certain temporal character of scientific knowledge, that is, they stated that knowledge based on scientific procedures is true at a given moment in time only. On the other hand, subsequent research and scientific discoveries may partially modify it or completely discard it, e.g.:

> I think that conventional medicine, however, always at every stage says what it says in the best faith. That is, it tells it like it is […], what it really knows best at any given moment. That is, it tells us the truth about what it has investigated at the moment [F, 35–44, U].

It demonstrates the understanding of the temporal character of some of the scientific findings. It was observed during the consultation that scientific content can change over time due to the influence of new discoveries and the work of other research groups. This demonstrates that participants recognize the necessity for continuous scientific endeavor yet simultaneously necessitates the provision of perpetual educational resources to the audience.

During the discussions participants emphasized also that it is not the personal views of scientists – such as being against vaccination – that matter, but rather the body of research on the topic and the scientific evidence that contribute to the general level of trust in science.

> Well, that is the thing with science as a whole and scientists, that it doesn't matter what they think […] That's not important. Only the research results matter. The results of studies, preferably such meta-analyses, of course [F, 25–34, U].

This is yet another example of how the current state of knowledge can be altered as a result of new research, discoveries and scientific publications. It is imperative that the influence of personal views, political, economic, worldview considerations and pressures from influence groups be excluded from the formation of knowledge.

Discussion

The statements that there is no scientific research without appropriate methods and tools, science is a human endeavor, and it is uncertain and has its limitations, may sound overly self-evident to professionals, researchers, and scientists. However, verifying whether ordinary citizens, who are not engaged in scientific research on a daily basis, embrace NoS principles in their everyday discussions presents an intriguing area of analysis.

Our findings revealed that Polish participants referred to all the aspects Shapin (1992) identified as key elements that should be communicated to the public regarding the scientific process. These include the collective basis of science, highlighting that no single scientist possesses all the knowledge within their field; the indispensable role of trust in scientific work and the vulnerability of good science to unethical practices; the contingency and revisability of scientific judgments, emphasizing that what is considered true today may be reassessed tomorrow without fault; and the interpretative flexibility of scientific evidence, acknowledging that competent and well-intentioned practitioners can arrive at differing conclusions from the same data.

Drawing from Bybee, Powell, and Trowbridge's (2008) classification of scientific literacy levels, Polish citizens' statements exhibited various dimensions of scientific literacy. These include functional scientific literacy, reflected in the correct use of scientific terminology; conceptual and procedural scientific literacy, demonstrated through an understanding of scientific processes; and multidimensional scientific literacy, where citizens contextualized science as a social phenomenon, linked it to trust, and recognized its dependence on funding sources.

This aligns with Shapin's (1992) assertion that it is essential not only to present research findings but also to explain the intricacies of the scientific process. He emphasized the need to communicate not just w h a t scientists know, but also h o w they know it, the level of confidence they have in their findings, and the reasoning behind their conclusions. Conveying both research findings and methodologies offers several benefits. It helps the public assess scientific debates (Yearley 1994), distinguish genuine science, and understand the uncertainties inherent in research. Without methodological context, findings lack depth, while methods alone may seem abstract. Integrating both enhances scientific literacy and fosters lifelong learning.

An integrated approach to communicating both research methods and findings can foster greater public trust in science by increasing awareness of the complexities of scientific work. A strategically implemented science communication strategy that incorporates NoS elements has the potential to enhance citizens' scientific literacy and equip them to better identify and resist pseudoscience and misinformation. Therefore, prioritizing science communication and strengthening the public's understanding of NoS can become a cornerstone of lifelong learning, empowering citizens to make informed decisions in an increasingly complex world.

Conclusion

In this study, we explored Polish citizens' perceptions of science-making, with a particular emphasis on the constitutive elements of NoS. The analysis revealed that participants were able to identify all key elements of NoS. Polish citizens most frequently recognized aspects related to the processes, tools, and products of science. To a lesser extent, they addressed the human elements of science and science limitations, although these were also explicitly articulated during discussions.

The participants' understanding of NoS was reflected in how they acknowledged key elements of research methodology, including identifying research aims, selecting appropriate methods, adhering to research procedures, drawing conclusions, and interpreting and communicating findings. They described the scientific procedure as rigorous, systematic, controlled, transparent, and replicable. Additionally, they characterized it as a long, multistage, and arduous process, emphasizing that it requires significant time, effort, and focus.

Participants demonstrated awareness of the global interconnectedness of scientific knowledge, noting that findings can now be quickly verified internationally.

However, they also recognized that this verification primarily applies to research communicated in English, limiting the accessibility and verification of findings published in other languages. Participants highlighted the crucial role of researcher and institution prestige, along with funding transparency, in building trust in scientific work.

Participants recognized that some scientific findings are only temporarily valid, highlighting the limitations of science and the elusive nature of absolute truth. They emphasized the significance of publication venues and independent verification, acknowledging that replication may yield differing results. Concerns were raised about the risks of misinterpretation, underscoring the value of collaboration in mitigating these issues through discussion and knowledge exchange.

References to NoS principles were most pronounced among participants with higher education, who used scientific terminology effectively. This suggests that those without higher education may have a less nuanced understanding of NoS, though this conclusion is limited by their underrepresentation in the study, warranting further research.

Additionally, selection bias may have influenced the study, as participants were inherently interested in science communication, limiting the generalizability of findings. However, the sample included individuals from various educational backgrounds and age groups, suggesting that active engagement with scientific information and lifelong learning enhance one's ability to critically assess research.

Bibliography

Adamczyk M. D. (2022) *Uczenie się przez całe życie jako element uczestnictwa społecznego osób starszych i ich aktywnego starzenia się*, "Zeszyty Naukowe Katolickiego Uniwersytetu Lubelskiego Jana Pawła II", no. 65(3), pp. 67–86, https://doi.org/10.31743/znkul.14471.

Blue G., Medlock J. (2014) *Public Engagement with Climate Change as Scientific Citizenship: A Case Study of World Wide Views on Global Warming*, "Science as Culture", no. 23(4), pp. 560–579, https://doi.org/10.1080/09505431.2014.917620.

Bybee R. W., Powell J. C., Trowbridge L. W. (2008) *Teaching Secondary School Science. Strategies for Developing Scientific Literacy*, 9th ed., Upper Saddle River, NJ, Pearson Merril Prentice Hall.

Day S. B., Goldstone R .L. (2012) *The Import of Knowledge Export: Connecting Findings and Theories of Transfer of Learning*, "Educational Psychologist", no 47(3), pp. 153–176, https://doi.org/10.1080/00461520.2012.696438.

Dorsah P. (2020) *Pre-Service Teachers' View of Nature of Science (NoS)*, "European Journal of Education Studies", no. 7(6), pp. 124–146.

Durant J. (1994) *What is Scientific Literacy?*, "European Review", no. 2, pp. 83–89, https://doi.org/10.1017/S1062798700000922.

Gyllenpalm J., Rundgren C. J., Lederman J., Lederman N. (2022) *Views About Scientific Inquiry: A Study of Students' Understanding of Scientific Inquiry in Grade 7 and 12 in Sweden*, "Scandinavian Journal of Educational Research", no. 66(2), pp. 336–354, https://doi.org/10.1080/00313831.2020.1869080.

Krzewińska A., Dzimińska M., Warwas I., Wiktorowicz J. (2021) *Komunikacja naukowa w Polsce. Szczepionki, medycyna alternatywna, zmiany klimatyczne, GMO pod lupą*, Łódź, Wydawnictwo Uniwersytetu Łódzkiego, https://doi.org/10.18778/8220-553-4.

Kuhn T. (1996) *The Structure of Scientific Revolution*, Chicago, IL, The University of Chicago Press.

Laal M., Salamati P. (2012) *Lifelong Learning; Why Do We Need It?*, "Procedia – Social and Behavioral Sciences", no. 31, pp. 399–403, https://doi.org/10.1016/j.sbspro.2011.12.073.

Lederman N. G., Abd-El-Khalick F. (1998) *Avoiding De-Natured Science: Activities That Promote Understandings of the Nature of Science* in: *The Nature of Science in Science Education, Rationales and Strategies*, W. F. McComas (ed.), Dordrecht, Kluwer Academic Publishers, pp. 83–126, https://doi.org/10.1007/0-306-47215-5_5.

Llorente C., Revuelta G., Dzimińska M., Warwas I., Krzewińska A., Moreno C. (2022) *A Standard for Public Consultation on Science Communication: The CONCISE Project Experience*, "Journal of Science Communication", no. 21(3), pp. 1–25, https://doi.org/10.22323/2.21030802.

Lombrozo T., Thanukos A., Weisberg M. (2008) *The Importance of Understanding the Nature of Science for Accepting Evolution*, "Evolution: Education and Outreach", no. 1(3), pp. 290–298, https://doi.org/10.1007/s12052-008-0061-8.

Malewski M. (2013) *Studia nad kondycją edukacji dorosłych*, "Edukacja Dorosłych", no. 1(68), pp. 9–23.

Matthews M. (2002) *Foreword and Introduction* in: *The Nature of Science in Science Education, Rationales and Strategies*, W. F. McComas (ed.), Dordrecht, Kluwer Academic Publishers, pp. xi–xxi.

McComas W. F., Clough M. P., Almazroa H. (2002a) *The Principal Elements of the Nature of Science: Dispelling the Myths* in: *The Nature of Science in Science Education, Rationales and Strategies*, W. F. McComas (ed.), Dordrecht, Kluwer Academic Publishers, pp. 53–70, https://doi.org/10.1007/0-306-47215-5_3.

McComas W. F., Clough M. P., Almazroa H. (2002b) *The Role and Character of the Nature of Science in Science Education* in: *The Nature of Science in Science Education, Rationales and Strategies*, W. F. McComas (ed.), Dordrecht, Kluwer Academic Publishers, pp. 3–39, https://doi.org/10.1007/0-306-47215-5_1.

McComas W. F. (2020) *Principal Elements of Nature of Science: Informing Science Teaching while Dispelling the Myths* in: *Nature of Science in Science Instruction*, McComas W. F. (ed.), Cham, Springer, pp. 35–65, https://doi.org/10.1007/978-3-030-57239-6_3.

McPhetres J., Rutjens B. T., Weinstein N., Brisson J. A. (2019) *Modifying Attitudes About Modified Foods: Increased Knowledge Leads to More Positive Attitudes*, "Journal of Environmental Psychology", no. 64(February), pp. 21–29, https://doi.org/10.1016/j.jenvp.2019.04.012.

Miller J. D. (1992) *Toward a Scientific Understanding of the Public Understanding of Science and Technology*, "Public Understanding of Science", no. 1(1), pp. 23–26, https://doi.org/10.1088/0963-6625/1/1/005.

Muszyński M. (2023) *Trzy wymiary całożyciowego uczenia się – na przykładzie gerontologii edukacyjnej*, "Edukacja Ustawiczna Dorosłych", no. 3(122), pp. 221–231.

Nelson C. E., Scharmann L. C., Beard J., Flammer L. I. (2019) *The Nature of Science as a Foundation for Fostering a Better Understanding of Evolution*, "Evolution: Education and Outreach", no. 12, article 6, https://doi.org/10.1186/s12052-019-0100-7.

OECD (2021) *OECD Skills Outlook 2021: Learning for Life*, OECD Publishing, Paris.

Ranney M. A., Clark D. (2016) *Climate Change Conceptual Change: Scientific Information Can Transform Attitudes*, "Topics in Cognitive Science", no. 8(1), pp. 49–75, https://doi.org/10.1111/tops.12187.

Rask M., Worthington R. (eds.) (2017) *Governing Biodiversity through Democratic Deliberation. Governing Biodiversity through Democratic Deliberation*, London, Routledge.

Schwartz R., Lederman N. (2008) *What Scientists Say: Scientists' Views of Nature of Science and Relation to Science Context*, "International Journal of Science Education", no. 30(6), pp. 727–771, https://doi.org/10.1080/09500690701225801.

Shapin S. (1992) *Why the Public Ought to Understand Science-in-the-making*, "Public Understanding of Science", no. 1(1), pp. 27–30, https://doi.org/10.1088/0963-6625/1/1/006.

Sullenger K., Turner S. (2002) *Nature of Science: Implications for Education an Undergraduate Course for Prospective Teachers* in: *The Nature of Science in Science Education, Rationales and Strategies*, W. F. McComas (ed.), Dordrecht, Kluwer Academic Publishers, pp. 53–70.

Weisberg D. S., Landrum A. R., Hamilton J., Weisberg M. (2021) *Knowledge About the Nature of Science Increases Public Acceptance of Science Regardless of Identity Factors*, "Public Understanding of Science", no. 30(2), pp. 120–138, https://doi.org/10.1177/0963662520977700.

Yearley S. (1994) *Understanding Science from the Perspective of the Sociology of Scientific Knowledge: An Overview*, "Public Understanding of Science", no. 3(3), pp. 245–258, https://doi.org/10.1088/0963-6625/3/3/001.

Online resources

WWV on Global Warming (nd.), https://globalwarming.wwviews.org/node/259.html (accessed: 25.01.2025).

World Economic Forum (2015) *New Vision for Education – Unlocking the Potential of Technology. World Economic Forum, BCG*, Geneva. https://www3.weforum.org/docs/WEFUSA_NewVisionforEducation_Report2015.pdf (accessed: 25.01.2025).

About the Authors

Aneta Krzewińska – Associate Professor, PhD in the humanities in the field of sociology, head of the Department of Methods and Techniques of Social Research (Faculty of Economics and Sociology at the University of Lodz, Poland). She is an author of numerous methodological publications. She implemented 30+ qualitative and quantitative research studies. Her scientific interests include: deliberative techniques, social consultations, social research methodology. She is actively searching for new tools to collect citizens' opinions and learn about the mechanisms of the research tools' acculturation. She carries out methodological tests on the techniques of group decision making and consensus reaching. She worked on implementing the participatory budgeting in the city of Lodz and designed public consultations using deliberative techniques in such areas as space planning, revitalization, culture, science. Following that she assessed the methodological value of the different techniques. These experiences resulted in authoring the book *Deliberation. Idea–Methodology – Practice* (Krzewińska, 2016), e-mail: aneta.krzewinska@uni.lodz.pl.

Małgorzata Dzimińska – PhD, Assistant Professor at the University of Lodz in Poland. Her main research interests revolve around higher education where she focuses on the topics of quality assurance, knowledge management, data use for educational improvement, science communication and community-based participatory research. She teaches using active learning pedagogies, presents at conferences and publishes in international journals. She is a member of Society for Research in Higher Education (SRHE) and the European Higher Education Society (EAIR), e-mail: malgorzata.dziminska@uni.lodz.pl.

Izabela Warwas – professor at the Faculty of Economics and Sociology at the University of Lodz. Head of department of labor and social policy. Her scientific interests focus on the issues related to science communication, human resources management, age and diversity management. Author and co-author of 140 publications. She participated, as a principal investigator, coordinator, specialist on evaluation and expert, in over 40 European projects. Moreover, she participated in several national projects ordered by the Ministry of Science and Higher Education, Ministry of Regional Development, marshal offices. Fellow at the University of Glasgow (2015) and participant STSM in The German Centre of Gerontology in Berlin (2017). She was awarded the Polish Academy of Sciences prize (2016, 2017). *The Cross-Cutting Activity (CCA) on science communication*, European Cooperation in Science and Technology (COST) and *The Sloan Research Network on Aging & Work* (Boston College) participant, e-mail: izabela.warwas@uni.lodz.pl.

Aneta Krzewińska – profesor uczelni, doktor habilitowany nauk humanistycznych w zakresie socjologii, kierownik Katedry Metod i Technik Badań Społecznych (Wydział Ekonomiczno-Socjologiczny Uniwersytetu Łódzkiego). Autorka licznych publikacji metodologicznych. Zrealizowała kilkadziesiąt badań jakościowych i ilościowych. Jej zainteresowania naukowe obejmują: techniki deliberacyjne, konsultacje społeczne, metodologię badań społecznych. Aktywnie poszukuje nowych narzędzi zbierania opinii obywateli i poznaje mechanizmy akulturacji narzędzi badawczych. Prowadzi badania metodologiczne nad technikami grupowego podejmowania decyzji i dochodzenia do konsensusu. Pracowała nad wdrożeniem budżetu partycypacyjnego w Łodzi oraz projektowała konsultacje społeczne z wykorzystaniem technik deliberatywnych w takich obszarach, jak planowanie przestrzeni, rewitalizacja, kultura, nauka. Następnie oceniała wartość metodologiczną poszczególnych technik. Doświadczenia te zaowocowały napisaniem książki *Deliberacja. Idea – Metodologia – Praktyka* (Krzewińska, 2016), e-mail: aneta.krzewinska@uni.lodz.pl.

Małgorzata Dzimińska – dr, adiunkt na Uniwersytecie Łódzkim. Jej główne zainteresowania badawcze koncentrują się wokół szkolnictwa wyższego, skupiając się na tematach zapewniania jakości, zarządzania wiedzą, wykorzystania danych do poprawy edukacji, komunikacji naukowej i badań partycypacyjnych opartych na społeczności. Prowadzi zajęcia z wykorzystaniem metod aktywnego uczenia się, uczestniczy w konferencjach i publikuje w międzynarodowych czasopismach. Jest członkiem Society for Research in Higher Education (SRHE) i European Higher Education Society (EAIR), e-mail: malgorzata.dziminska@uni.lodz.pl.

Izabela Warwas – profesor uczelni na Wydziale Ekonomiczno-Socjologicznym Uniwersytetu Łódzkiego. Kierownik Katedry Pracy i Polityki Społecznej. Jej zainteresowania naukowe koncentrują się wokół zagadnień związanych z komunikacją naukową, zarządzaniem zasobami ludzkimi, zarządzaniem wiekiem i różnorodnością. Autorka i współautorka 140 publikacji. Uczestniczyła jako główny badacz, koordynator, specjalista ds. ewaluacji i ekspert w ponad 40 projektach europejskich. Ponadto uczestniczyła w kilku projektach krajowych zamawianych przez Ministerstwo Nauki i Szkolnictwa Wyższego, Ministerstwo Rozwoju Regionalnego, urzędy marszałkowskie. Stypendystka Uniwersytetu w Glasgow (2015) oraz uczestniczka STSM w Niemieckim Centrum Gerontologii w Berlinie (2017). Wyróżniona nagrodami Polskiej Akademii Nauk (2016, 2017). Uczestniczka Cross-Cutting Activity (CCA) w zakresie komunikacji naukowej, European Cooperation in Science and Technology (COST) oraz The Sloan Research Network on Aging & Work (Boston College), e-mail: izabela.warwas@uni.lodz.pl.