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SCIENCE AND SOCIETY - A NEW ERA FOR SCIENCE COMMUNICATION IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

Abstract: The high degree of interest in scientific topics (science and research) has been observed especially since the pandemic. This includes the ongoing transition of the chemical industry toward sustainability because the accompanied changes have to be coordinated in dialogue with society. Parallelly, there is increasing interest in science communication in general, as well as the increasing need for its proper understanding. How we communicate is probably today as important as what we communicate. The purpose of this study is to explore how society perceives science, research, scientific results, and their role in the modern world. The method used in the study was a diagnostic survey, and the data was collected using an online questionnaire. This study used a quantitative method. The results showed that science communication needs to be developed much more with special attention paid to the economic, social, and political context. The results analysed and integrated in this article could provide substantive suggestions and help develop science communication.

Keywords: science communication, society, teaching, scientific research

Introduction

We live in very complicated times and never before have we had such rapid and easy access to information, which also means information that is not true, i.e. fabricated. Probably each of us has come across misinformation, fake news about the climate, nuclear energy, new medicines, more energy-efficient materials, ways of generating energy, or green chemistry [1, 2]. This was particularly evident in the past pandemic period. The susceptibility of society to this type of disinformation is high and often results from the complexity of issues, an insufficient level of knowledge on a given topic, media competence, or, unfortunately, the politicisation of the topic. By widely communicating results based on the scientific method, science forms a solid counterweight against fake news and the misconception and gives possibilities not to ignore scientific evidences to conscious members of society.

According to the Pew Research Center 2019 survey [3], in the medical and nutrition sectors, American society demonstrates a tendency to value the opinions of science practitioners, who directly provide treatments and recommendations to the public above

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those of researchers working in the same area. Nearly half (47 %) of respondents highlighted that dietitians provide 'fair and accurate information' 'all or most of the time' dietitians provide 'fair and accurate information', while only 24 % of respondents believe that equally adequate information is provided for at least most of the time by nutrition research scientists. However, these data should be contrasted with the 86 % rate of respondents who claim to have at least 'a fair amount of confidence' that scientists act in the public interest. It should be noted that similar patterns are also observed in Europe [4].

The compilation of the foregoing data leads to the question where the problem is centered in the relationship between scientists and society. The diagnosis of such a problem is accompanied by a number of misconceptions. Traditionally, the perception of this issue is centered on the concept of 'trust'. However, increasingly in the academic doctrine, an important distinction is drawn between the general attitude to science and the 'trust to science' in specific matters. Therefore, according to Leshner [5]: "Science and public policy experts have long taught that important decisions [.....] are rarely, if ever, made solely on the basis of science, but are based on both facts and values, or on facts and personal experience". As a consequence, Hendriks et al. [6] reported that "trust in science develops and changes in light of the public's views about specific scientific topics". Therefore, while identifying the problem, greater leverage shall be put upon sociocultural backgrounds and the values of the particular society.

This observation provides a basis for the conclusion that the genuine problem lies in the inadequate strategies for science popularisation. Such remarks can be amplified by one additional notion. Approximately 20 % of Americans believe that scientists are 'transparent about possible conflicts of interest with industry groups' all or most of the time. The findings of the survey [1] undoubtedly provide an important guide for the conduct and dissemination of scientific research results.

Scientists are generally perceived as experts in a given field of science [7, 8]. They possess extensive knowledge and abilities that enable them to apply complex techniques and procedures to conduct research. With this in mind, it can be said that it is a narrow group of people who stand out from the rest of society. As such, they may have difficulty making themselves more understandable to others. However, science seems to be unattractive to ordinary people who are not able to understand its complicated language and techniques; the public does not understand much of what scientists do. As Seethaler et al. [9] rightly noted, scientists are often perceived as people who cannot talk about their work and its effects in an accessible way.

By communicating science publicity, it is possible to give a human face to a field that can be viewed as cold and aloof. Its improvement seems particularly crucial for millions of people around the world because the results of these studies and understanding of their results can determine people's lives. It is obvious that the most important thing is helping scientists bridge the gap between academies and society, and this topic has been taken up by many authors [10-14]. The question arises how to popularise science in order to show its value and importance not only for researchers, but first of all to the large majority of society.

Science communication plays a key role, as it directly forms the visibility and reputation of scientists. Another problem is related to the personal credibility of researchers with respect to the transparency of their work ethics [3]. An adverse effect of inadequate communication strategies lies in the erosion of the reputation of scientists in the eyes of the society. Beyond that, the adequacy of communication strategies influences the scientist's

career, such as promotion, grant recruitments and the definition of research priorities [15-19].

Easy access to the news has resulted in an information overload. The cost of information diffusion, according to Wu [20], facilitates 'to weaponise the speech as the tool of speech control'. As Eysenbach [21] accurately claimed, the digital media are deprived of traditional 'gatekeepers', e.g. as journalists and editors. Consequently, such tendencies lead to undermine the information security of the societies as well as open a gate for disinformation and manipulations of facts. Therefore, it is essential to notice the crucial role of adequate science communication strategies in the era of digitalisation [6, 22-25]. It must be underlined that the ability to judge the truthfulness of the information given is vital not only from the point of view of the political decision-making process, but also from the daily choices of individuals regarding their health and safety [26, 27].

In effect, implementing adequate popularisation strategies remains a critical task for contemporary science [28-32]. Simultaneously, the society shall be treated as the essential partners within this communication.

Furthermore, adequate science communication strategies enable researchers to develop new skills indispensable in their academic pursuits [33]. Unquestionably, public speaking skills play a crucial role for the grant application, conference presenting, and didactics.

In this context, the adequacy of science communication can accomplish three things. First, we must 'combat negative stereotypes' regarding science [33]. Second, it can demonstrate the usefulness of science to lay people. Finally, it can overcome allegations regarding the area of research ethics and transparency.

Purpose of the study

The purpose of the research was to provide a theoretical description of the situation related to the presence of scientific knowledge and research results in society's awareness by collecting their opinions about science and scientific research in Poland. The opinions collected allow for recognition of the actual situation of science communication, as well as recognition of areas requiring support and further development. The research was designed to provoke scientists to reflect on the need for proper and effective preparation for science communication and their ability to provide society with opportunities for participation in different forms of communication and positive outcomes, also in the aspect of expected change in the awareness of society in the future.

The research problem was analysed using sub-problems listed below:

- Research question no. 1: Does gender / age / place of residence / status of: pupil, student, teacher / school, university subject, area of experienced have the effect on the opinion that current scientific knowledge, conducted research, and the application of scientific results in practice are important to the respondent?
- Research question no. 2: Does gender / age / place of residence / status of: pupil, student, teacher / school, university subject, area of experienced have the effect on the opinion that current scientific knowledge, conducted research, and the application of scientific results in practice are important to contemporary societies?
- Research question no. 3: Does gender / age / place of residence / status: pupil, student, teacher / school, university subject, area of experience have the effect on the opinion that every citizen has easy access to scientific knowledge, conducted research, and its achievements in your country?

- Research question no. 4: Does gender / age / place of residence / status: pupil, student, teacher / school, university subject, area of experience have an effect on the opinion that science research conducted in your country represents an important contribution to world science?

Research methodology

Methods

The method used in the study was a diagnostic survey using a questionnaire developed by the authors. The survey was carried out in the form of an online version in two steps: step no. 1 - pilot step, step no. 2 - the actual survey stage.

Questionnaires are a popular method of research, providing a fast, efficient and inexpensive way of collecting large amounts of data from large amounts of samples. These tools are especially effective in measuring the behaviour, preferences, intentions, attitudes and opinions of the subjects. Using open and closed research questions allows researchers to obtain qualitative and quantitative data, and provides a more comprehensive result [34].

The tool used in this study is a questionnaire using a Likert scale of five levels (1 - absolutely not; 5 - absolutely yes). The questionnaire consists of 7 closed questions. This questionnaire was validated by an expert in science communication from Poland. The reliability of the questionnaire was tested and confirmed for the first time in a pilot study with more than 100 respondents from Poland.

Participants

The research was carried out on a randomly selected sample of all participants who completed the questionnaire. Figure 1 presents the characteristics of the respondents.

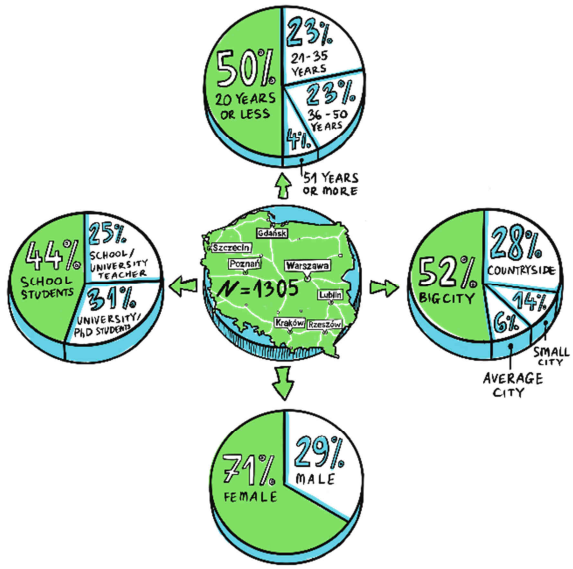

Fig. 1. Characteristic of the respondents (N = 1305)

Context

The rapid development of new technologies and digital media provides wide access to all information, regardless of country and time limits [31]. Access to information and the ability to select it and assess its credibility are basic skills that will allow the conscious use of digital media [22, 23, 25].

Disinformation campaigns that intensified during the pandemic are aimed, among others, at polarising society by imposing a narrative that evokes a sense of threat, fear, as well as reinforcing antiscientific theses or antagonising specific people or groups. Examples of such actions are the deliberate discrediting of COVID-19 vaccines; issues related to sustainable development, sustainable development of chemistry and ecology are extremely common topics [1, 35].

Therefore, it seems that actions are necessary to achieve the overarching goal of reliable and objective information available to all human beings. And this is where science popularisation has to intervene [36].

Data collection

The survey was conducted during the first part of the 2021 year (pilot step) and the next two parts during the summer semester of the 2021/2022 and winter semester of the 2022/2023 academic year. The invitation to participate in the survey was sent by email to potential respondents (schools, universities, and institutions). Authors also spread an invitation based on official and private ways (e.g. social media).

Data analysis

For the purposes of this article, some parts of a questionnaire have been selected for analysis. Statistical calculations were performed using the Statistica 13 programme of the StatSoft company for the assumed significance level equal to $\alpha = 0.05$. Pearson's chi-square test (χ^2) was used in order to demonstrate the relationships for the nominal variables, we obtain statistical significance in the event that the calculated *p*-value is lower than the assumed significance level $\alpha = 0.05$. Furthermore, the correlation (strength of association) between the variables considered was calculated using Cramér's V, which is interpreted only in the case of significantly statistical variables ($p < 0.05$). A classification scale was used: very weak correlation below 0.2; weak/low correlation from 0.2 to 0.4; moderate correlation from 0.4 to 0.6; strong correlation from 0.6 to 0.8; very strong correlation from 0.8 to 0.9; almost complete relationship from 0.9 to 1.0.

Findings and discussions

Q.1. Does gender / age / place of residence / status of: pupil, student, teacher / school, university subject, area of experience have the effect on the opinion that current scientific knowledge, conducted research, and the application of their results in practice are important to the respondent?

72.3 % of the respondents answered "definitely yes", and another 22.1 % - "rather yes". Among the respondents who answered "definitely yes", the dominant group are residents of large cities (over 100,000) and mature people (36-50 years old). The number of the declared "definitely yes" answers is decreasing in the row: teachers; Ph.D. students, and students; pupils (Fig. 2).

Teachers are much more likely than students to believe that current scientific knowledge, conducted research, and application of scientific results in practice are important to them (Chi square test $\chi^2 = 137.73$; $p < 0.05$).

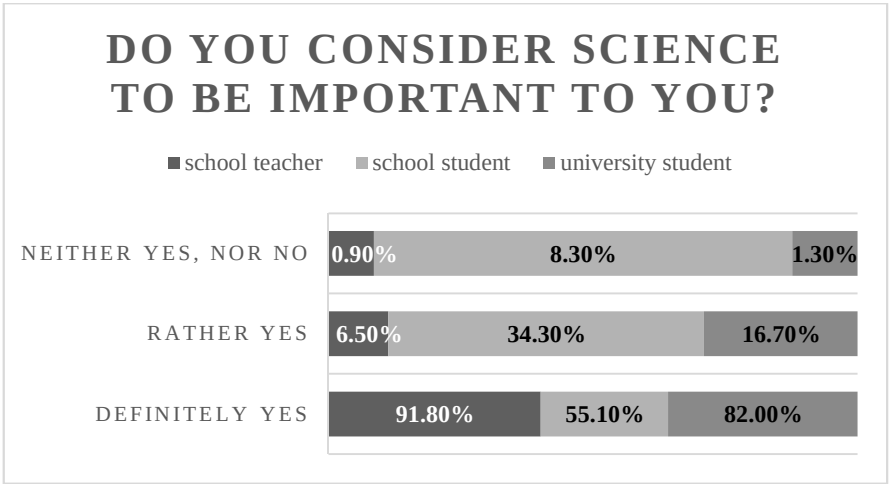

Fig. 2. How did respondents from different groups (status: students, teachers) answer Question 1?

It seems that thinking about the significance of science for its own sake, people start to pay more attention to their own life (not to the whole society, that is to say; everyone but themselves) and notice how much science has given them and changed in their lives (and it still does). It is visible at every turn and they realise that science has given them their standard of living. Mature people prevail because they have seen the development of science over the years (for instance, the development of a phone, television, or the Internet). Younger people do not have this perspective.

The decreasing number of responses among teachers, Ph.D. students, and students is directly related to the age of the respondents (the older, the more aware, and more they experience the presence of science in life). Another possible reason may also be the fact that a teacher, by definition teaching his own subject, often tries to find as many scientific aspects as possible in his own life to impart it to school students. This is the reason why the teacher can see the high relevance of education. Students and Ph.D. students delve into science of their own accord, and therefore they probably see how important science is for them on a day-to-day basis, and nobody tries to convince them to it (as it is in the case of school students; that is why students and Ph.D. students rank higher). They do not look for applications of science wherever they can find them, as teachers may do to encourage school students to learn.

Q.2. Does gender / age / place of residence/status of: pupil, student, teacher / school, university subject, area of experience have the effect on the opinion that current scientific knowledge, conducted research, and the application of scientific results in practice are important to contemporary societies?

65.8 % of the respondents answered “definitely yes”. The dominant group among these respondents is residents of a large city (over 100,000 inhabitants), 67.9 %, and rural residents, 65.9 %. The percentage of “definitely yes” answers decreases slightly with age

from 67.6 % (20 years or less) to 59 % (51 years or more). It also decreased slightly from students and Ph.D. students (69.8 %) to teachers (61 %).

However, the high value of the "definitely yes" responses pleases; it may be due to various reasons. One of them is the fact that today we live in the 'age of knowledge', knowledge is ubiquitous (irrespective of the place of residence); every once in a while, people are faced with new technologies and new solutions to various health or environmental problems. This generates the sense that the development of science is indispensable for societies to progress and still exists.

The effect of age can be difficult to explain. It may be worth paying attention to the fact that young people still "experience" knowledge and science, which is behind it, either at school or at university. This leads to a sense of its significance in everyday life, since it is its direct part. Most older people must exert some effort to experience science, for example, by reading articles, watching the news, or using new technologies. For this reason, science often does not have to be a direct part of their life (at least in the sense that they are directly seen by them). That is why they certainly feel that science is not as necessary for everyday life.

In the context of the decline of the sense of importance of science to societies from students to teachers, it seems that students who start studying are somehow convinced about the significance of science, for that reason among others they want to immerse themselves in science and study. Since they have not had a wide knowledge so far (about how science works and what it can bring), they feel that it has many undiscovered aspects and is potentially very important for the development and life of societies. The more knowledge people gain and the more they transfer it (teachers), the stronger they may begin to feel that science is not so 'unusual' and indispensable. At the same time, they may think that its development does not give as much as they imagined it would do during their college days.

In this part of the survey, one more research question appeared: What do you think of science and scientific research as important to Polish society? 49.2 % of the respondents answered "definitely yes", and another 33.9 % - "rather yes". Both in the case of "definitely yes" and "rather yes" answers, the fewest respondents live in rural areas and small towns.

People 36-50 years of age (Fig. 3) are much more likely than others to believe that science is not important to the Polish society (Chi square test $\chi^2 = 42.43$; $p < 0.05$).

It was surprising that teachers (Fig. 4), considerably more often than university students and pupils, say that science is not important to Polish society (Chi square test $\chi^2 = 32.44$; $p < 0.05$).

Another reason may be the awareness of young people about how little they still know about the results of scientific research and how much science can bring people to everyday life. Perhaps teachers often see that what they teach may not be so important to the entire society. Unfortunately, surely teachers' current social status and a bad situation in terms of work and earnings contribute to such an opinion of Polish teachers on the subject in general.

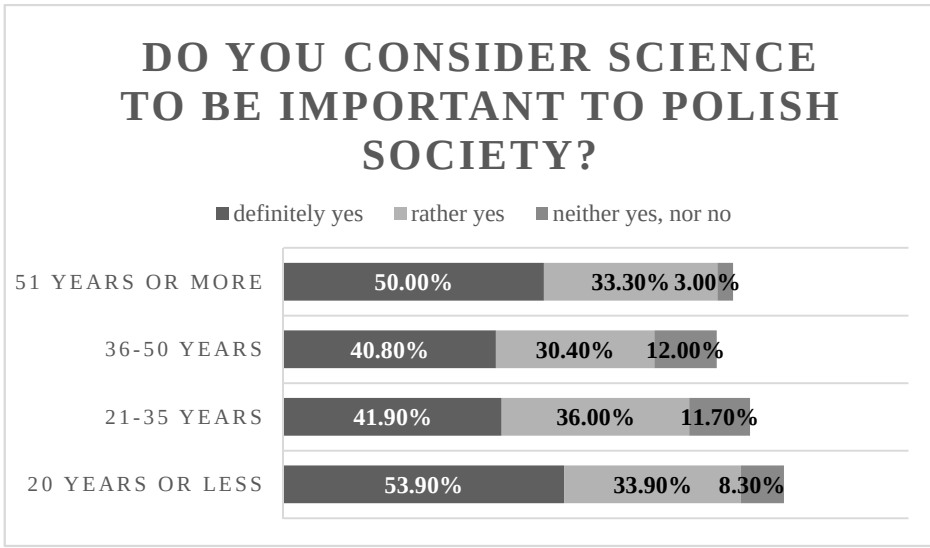

Fig. 3. How did respondents of different age answer Question 2?

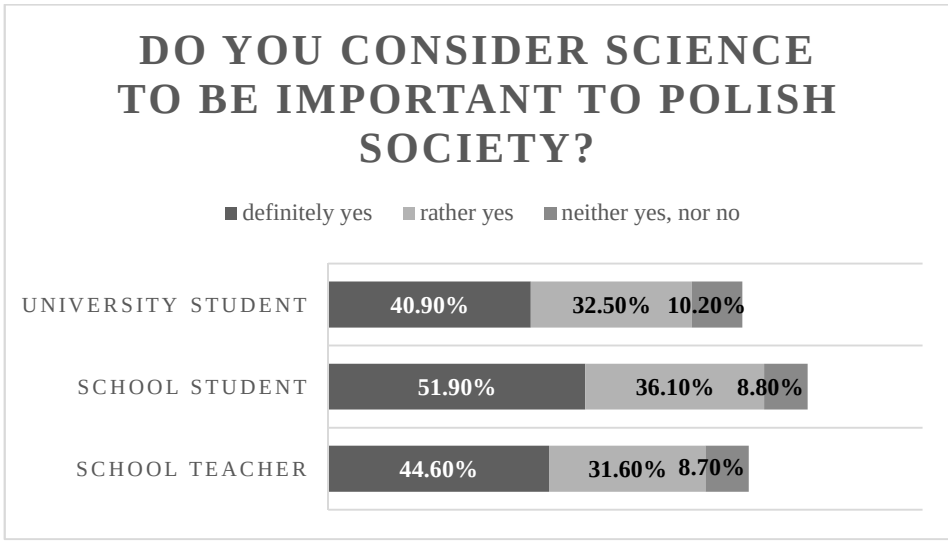

Fig. 4. How did respondents from different groups (status: students, teachers) answer Question 2?

Q.3. Does gender / age / place of residence / status: pupil, student, teacher / school, university subject, area of experience have an effect on the opinion that every citizen has easy access to scientific knowledge, conducted research, and its achievements in your country?

48.9 % of the respondents answered, “rather yes” and “definitely yes”; the respondents represent small towns and villages and are between 21 and 35 years old; have the status of a student and a doctoral student.

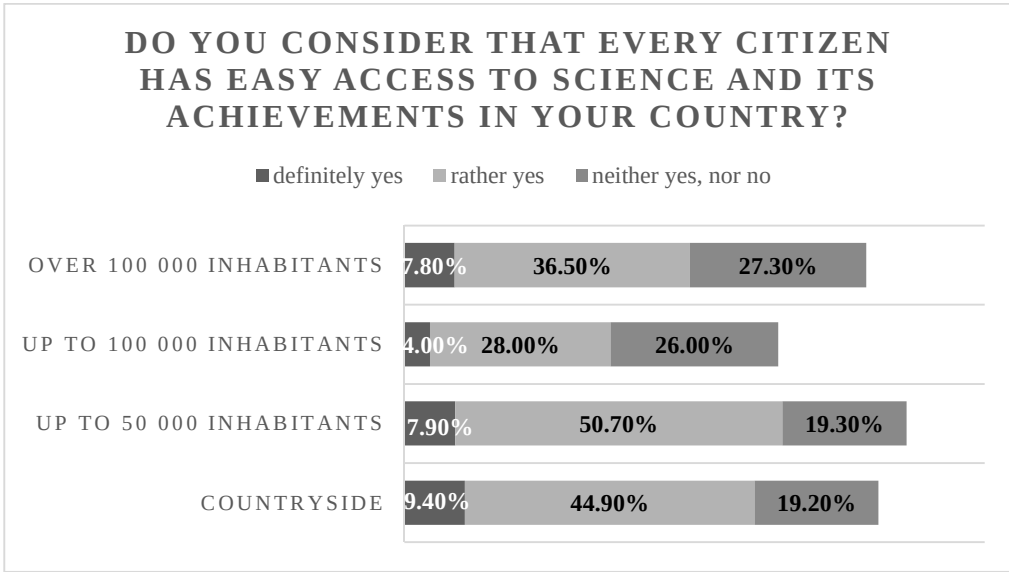

Fig. 5. How did respondents from places of various sizes answer Question 3?

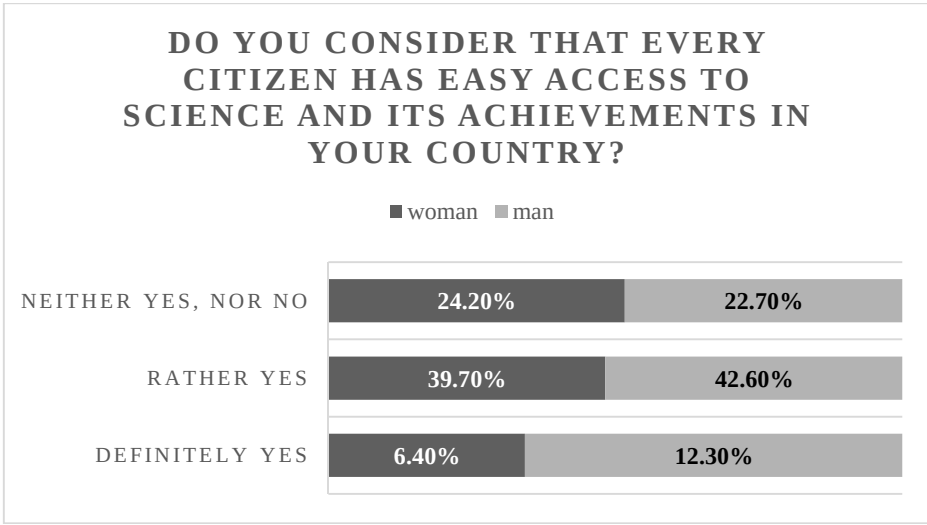

Fig. 6. How did women and men answer Question 3?

People living in large cities (up to 100,000 inhabitants; Fig. 5) more often believe that in Poland every citizen has easy access to scientific knowledge and its achievements

(Chi square test $\chi^2 = 22.58$; $p < 0.05$). It seems obvious that large cities offer many opportunities, for example, to contact universities, scientists, or participate in various forms that popularise scientific research and its possible application in everyday life.

Women (Fig. 6) more often than men disagree with the idea that in Poland all members of society have easy access to science, scientific knowledge, and its achievements (Chi square test $\chi^2 = 18.396$; $p < 0.05$).

Q.4. Does gender / age / place of residence / status: pupil, student, teacher / school, university subject, area of experience have an effect on the opinion that science and scientific research conducted in your country represents an important contribution to world science?

Only 14.6 % of the respondents, who live mainly in large cities (more than 100,000), are "definitely yes". 39.3 % of the respondents believe that it is "rather yes", and these are mainly respondents aged 21-35 (which is in line with the largest number of these indications for students and Ph.D. students) and over 51 years of age.

Many people probably know that Polish scientists have an important contribution to world science. However, it is difficult for them to indicate some of them from history, not to mention those from modern times. In relation to this, many responses are limited to 'rather yes' - due to the lack of certainty. Students and Ph.D. students often answer like this for a rather simple reason: they themselves are up-to-date due to contact with science; therefore, they remember the history of Polish science, and undoubtedly they also know the names of currently important Polish scientists.

People under 20 years of age (Fig. 7) often discover more than other age groups that Polish science does not make an important contribution to world science (Chi square test $\chi^2 = 111.5$; $p < 0.05$).

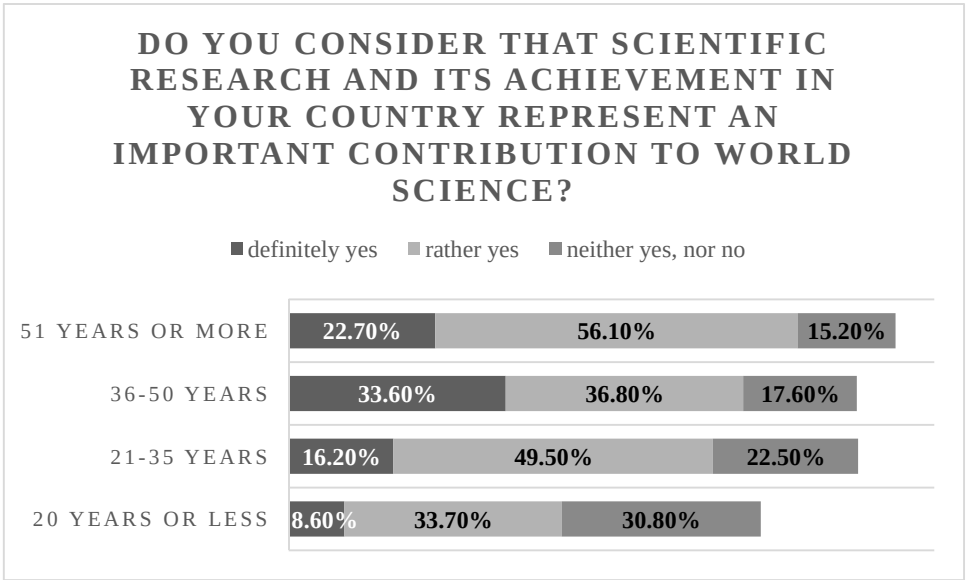

Fig. 7. How did the respondent of different age answer Question 4?

Unfortunately, this shows that young learners often do not know much about Polish science and scientific research; probably it may be indicated that not enough emphasis has been placed during young people's education on showing Polish science in the world.

Teachers (Fig. 8) have responded considerably more often than students that Polish science does not make an important contribution to world science (Chi square test $\chi^2 = 121.218$; $p < 0.05$).

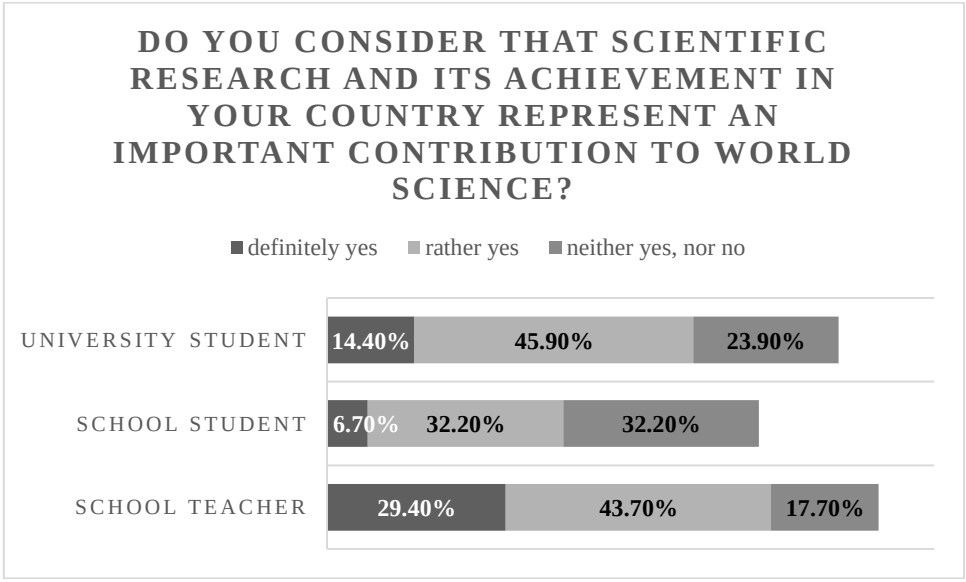

Fig. 8. How did respondents from different groups (status: students, teachers) answer Question 4?

Perhaps teachers do not see the contribution of Polish science to the subjects they teach. Perhaps there is too little emphasis on this in the core curriculum or in school/university programs and school/university textbook. And they may evaluate this not from the perspective of their own knowledge, but rather the knowledge they share with their students.

Conclusion

A necessary factor in the development of science and in particular in increasing its impact on society and the economy is communication and dialogue. This is also true for the ongoing transition of the chemical industry toward sustainability because the accompanied changes have to be coordinated in dialogue with the society. Science communication is an integral part of science and needs to be addressed with seriousness and appreciation, acting effectively and professionally. Engaging the public in this dialogue also provides valuable knowledge to scientists, as the opinions created take into account different perspectives. Communication in science can become a promising career path for young people, it strengthens the cultural importance of science, and hence scientists gain more influence on important policy decisions. In the act of communication, the recipient must

think critically and must know how to separate opinions from facts, control emotions, argue, and not fall into the trap of reasoning.

Proper school education determines how critical citizens will be, i.e. whether they will be innovative and open to various life activities, including learning about the results of scientific research and the possibility of their application in everyday life [37-39].

Significant and important factors were observed: gender inequalities in science, the problem of interculturality in science communication, and ethical threats resulting from unequal access to knowledge and science.

The global idea of sustainability should become a priority focus area for schools, not limited to the topic of climate and environmental risks.

One of the objectives of formal and informal education in any (more or less) developed country should be to transmit enough scientific knowledge about processes in the biosphere and products encountered in daily life. Teachers at school should encourage young people to learn about science and scientific results during well-created didactic situations in class. Teachers who could do this should be better educated in this area. It must involve some changes in education: the core curriculum, school/university programmes, textbook, and handbook should present actual state of science, scientific achievements, and their role in the development of society. In the next proposal, universities should offer science communication programming that includes obligated courses that may lead to a certificate or degree of specialisation. Much more offers scientists, journalists, teachers, and educators the opportunity to collaborate in formal professional training. Perhaps a new job perspective as a science communicator should be considered.

Global and systemic solutions are needed for all the topics mentioned above.

So it is worth science communication? Yes, because popularisation is an investment. We must establish credibility and support for science by demonstrating the importance of our research and supporting the informed public. If we want the public to be convinced of what we do, they must know first. It is worthwhile to promote science to demonstrate its interest, that it is not at all hermetic and that it is simply attractive. It is ultimately our commitment to society, which funds the activities of the public universities through taxes.

Acknowledgements

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