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SCIENCE COMMUNICATION IN HIGHER EDUCATION: GLOBAL PERSPECTIVES ON THE TEACHING OF SCIENCE COMMUNICATION

Training researchers and planning science communication and dissemination activities: testing the QUEST model in practice and theory

Ebe Pilt and Marju Himma-Kadakas

Abstract

This study tests the potential of using the QUEST model in science communication teaching and applying the model in planning communication and dissemination (C&D) activities for research applications. Based on the training analysis, we reason that the QUEST model provides relevant criteria for understanding the function of science communication. We argue that the QUEST indicators create a theoretical foundation that can be applied in science communication courses at different levels of higher education. However, the model functions better as a supportive tool for reasoning and perceiving communication activities. The qualitative analysis of research applications' C&D activities indicates the applicability of the QUEST model for analysing C&D activities, and single indicators of the model are evident in most of the conducted activities. In the theoretical framework, we look at the dependence of the quality of science communication on general trends: the functioning of deficit and dialogical or deliberative communication models in contemporary society and in the context of mediatisation.

Keywords

Professionalism, professional development and training in science communication; Science and media; Science communication: theory and models

DOI

https://doi.org/10.22323/2.22060204

Submitted: 27th May 2023
Accepted: 6th October 2023
Published: 11th December 2023

Introduction

Science communication bridges the scientific community and the public, allowing for the dissemination and understanding of knowledge. This is especially essential today when societies expect science to solve local and global crises. Over the last forty years, different ways of thinking have shaped the value stream around science communication. Contemporary science communication functions in a post-normal and information-saturated communication and media environment: "The field is challenged by three contexts: (1) 'post-normal situations' of coping with uncertainties, value questions, an urgency to act, and associated political pressures; (2) a dramatically changing media environment, and (3) a polarising discourse culture.” [Brüggemann, Lörcher & Walter, 2020] This affects both the way science communication is practised and taught today.

Starting with Bodmer’s [1985] report “The Public Understanding of Science” (PUS), the demand for science communication has been highlighted that could make science more accessible and understandable to the public. The focus was on scientific literacy and measures to communicate more knowledge to create a more informed public while improving the general attitude towards science. As a side effect of PUS, various so-called deficit models emerged [Bauer, Allum & Miller, 2007; Short, 2013; Trench & Bucchi, 2015]: public *deficit of scientific literacy*, a public *deficit of knowledge*, a public *deficit of “right” attitudes, trust deficit, expert deficit*, the *crisis of confidence*, etc. [Bauer, 2009].

All these models assume that the public lacks knowledge, interest, or trust in science and that scientists need to address these deficits in their communication [Durant, 1999]. Nevertheless, the problem may be elsewhere: reluctance to accept scientific knowledge might not be about a ‘lack of public understanding’ of the science but rather a difference in values or viewpoints and ways of thinking [Hansen, 2016]. Therefore, science communication is moving from deficit models to dialogue-based approaches [Jonsson, Grafström & Klintman, 2022; Szüdi et al., 2022; Trench, 2008]. But this process is prolonged. The conversation-based science communication models are less hierarchical and assume an equal partnership between scientists and the public. The same applies to modern ways of teaching. This also means different training practices for deliberative debate, but also critical thinking and open- mindedness, accepting the coexistence of different ways of thinking, and being able to listen or cooperate [Cattani & Mastroianni, 2021]. According to the dialogue model in science communication, knowledge from non-scientific sources, such as cultural and experiential knowledge, is regarded as important as scientific knowledge [Dietz, 2013; Reincke, Bredenoord & van Mil, 2020]. But so-called post-truth or post-normal situations have also somehow created the antithesis of the deliberative systems, indicating also the unwillingness to listen or consider the other side [Bächtiger, Dryzek, Mansbridge & Warren, 2018]. Therefore, it can also be seen that unless there is no fundamental change in the value stream of science communication, most scientists might still hold on to the deficit model when engaging with non-scientific audiences [Besley, Dudo & Yuan, 2017; Davies, 2008; Reincke et al., 2020].

It is not the quantity of scientific communication that matters but the quality nowadays, and this is relevant for any communication model — a deficit or a dialogue. The change in quality does not happen by itself. It also requires changes in the teaching or training of science communication. Whenever quality is discussed in the context of science communication, it is to be perceived as something that is lacking or needs to be improved [Olesk et al., 2021]. The quality of science communication is increasingly vital. During current cluster crises and information overload, poor communication can lead to misunderstandings, misinformation [Ecker et al., 2022], and science denial or scepticism that harms individuals and society. The redundancy of (scientific) information entails risks to science communication quality [Fähnrich, Weitkamp & Kupper, 2023]. Theoretical foundations of science communication stem from the deficit model, indicating a deficit in public knowledge. These foundations have been aimed at disseminating research results to fill the knowledge gap in society. Our study shows that mediatisation theories also support the so- called old deficit models, but do not support a real dialogue in society. The mediatisation narrates how science communicators follow media logic to attract media attention and audiences [Konkes & Foxwell-Norton, 2021]. In this case, the media also shapes how we communicate research results and sets the rules for scientific communication. However, there may be more efficient ways to share knowledge with society. The essential target groups must be better targeted, and messages reaching important target groups can be random. In information-saturated environments, there is a need for the sense-making of evidence-based information. Thus, the research gap lies in finding the theoretical foundations and practical concepts to support deliberative and dialogical science communication in society. Good science communication is also subject to the necessary quality criteria.

QUality and Effectiveness in Science and Technology (QUEST) model [Mannino et al., 2021; Olesk et al., 2021] is developed to support science communicators in improving the quality of their work. The model is framed into three quality dimensions, which are divided into twelve quality indicators: (1) trustworthiness and scientific rigour: *scientific, factual, balanced, transparent;* (2) presentation and style: *clear, coherent and contextual, spellbinding, interacting with the audience;* (3) connection with the society: *purposeful and targeted, impactful, relatable, responsible*. [Olesk et al., 2021] This research article focuses on the possibilities and obstacles of using the QUEST model in (1) teaching science communication to PhD students and (2) applying the model in planning and conducting communication and dissemination (C&D) activities for research projects.

By using (1) PhD students' training analysis and (2) application analysis and interviews we test the QUEST model as a science communication training and C&D tool to position its function in earlier and novel theoretical foundations of science communication.

Literature overview: mediatisation in relation to quality indicators

For a long time, in parallel with the changes occurring with different deficit and dialogue models, *mediatisation* has been considered a key theoretical concept for contemporary media and communications research [Couldry & Hepp, 2013]. The mediatisation of science is considered an empirical fact. However, science's media resistance is relatively high [Rödder & Schäfer, 2010] — still, the communication of science to non-scientists is rarely unmediated and scientific knowledge reaches the general public mainly through journalistic media [Delicado, Rowland & Estevens, 2021]. The concept aims to explain media's crucial role in everyday life and social contexts [Lundby, 2009; Couldry & Hepp, 2013].

In broad terms, we see mediatisation as a concept employed to critically analyse the interplay between transformations in media and communications and shifts in culture and society [Couldry & Hepp, 2013]. The mediatised world is dominated by media logic, transforming and shaping the meanings of knowledge of social institutions [Altheide, 2013]. At the same time, the dominance of media logic can act as a trap [Jonsson, Brechensbauer & Grafström, 2022] for science communication, hindering real dialogue between science and society. On the one hand, in our contemporary mediatised environment, playing by the media rules helps to reach the broadest possible audience. Still, if science communication functions mainly according to media logic and focuses primarily on mass communication, more personal and better-targeted communication opportunities remain in the background. Therefore, crucial social target groups may not be covered. The deficit model fits particularly well with media logic because it requires immense scientific information to be disseminated to the public. Essentially, it is one-way didactic communication rather than audience-oriented or dialogic [Trench, 2008].

2.1 Turn to deliberative science communication

As an old concept, media logic is good at reaching mass audiences, but its impact may still be remote. Those tools are resource-intensive, but at the same time, these activities have the most significant impact. To improve this, a shift in general attitude is necessary so that the so-called common sense concept [Bauer, 2009; Bauer et al., 2007; Jonsson, Brechensbauer & Grafström, 2022] and dialogue-based — deliberative communication practices [Dietz, 2013] could become the basis of the conversation between science and society. But these developments also have their challenges and bottlenecks.

Deliberative communication could be a powerful tool in science communication [Dietz, 2013] to encourage engaging and thoughtful discussions with different audiences [Longnecker, 2023]. This involves encouraging individuals to take a stand by listening, debating, and seeking arguments — it would be the best and broadest way of creating a mutually respectful meaning-creating process among equals [Englund, 2006]. Deliberative communication also means that different values — concepts and beliefs — are equally represented besides scientific knowledge and facts [Dietz, 2013]. Citizen juries and assemblies are examples of the processes of deliberative democracy [Wells, Howarth & Brand-Correa, 2021]. In their case, science must be a part of the discussion, but as a method of science communication, citizen juries and assemblies might not work well — the fundamental essence of science communication would disappear if it changed from fact-based to opinion- or value-based entirely.

Especially during contemporary cluster crises (including wartime in Europe), when our daily life has a slightly different dynamic, a well-tested model of risk communication is considered a better tool [Kara & Fischhoff, 2023]. Risk communication also has an essential conversation component: "Unlike traditional science communication, risk communication requires dialogue because there is no way of knowing what information people need without talking to them. — Risk communication can structure the dialogue needed for science and the public to work together more effectively" [Kara & Fischhoff, 2023, pp. 58, 61]. This internal development and change in the science communication culture require more strategic communication choices [Besley & Dudo, 2022a; Kessler, Schäfer, Johann & Rauhut, 2022]. The profound changes in society, media, and communication surroundings must also be considered in science communication teaching and training.

Drawing from these theoretical foundations — the dependence of science communication quality on the deficit model and mediatisation, — we form three research questions (RQ):

RQ1: *How does the QUEST model function in reasoning and perceiving science communication in PhD students' training?*

RQ2: *What QUEST model indicators are evident in science C&D activities of research applications?*

RQ3: *How do researchers reason using the QUEST model's indicators in planning communication activities in research applications?*

Methods and data

We combined qualitative methods of interviews, group interviews and textual analysis. For clarity, we divide the analysis of the study into two groups: (1) training analysis and (2) application analysis and interviews. In both analysis groups, we used the QUEST model [Olesk et al., 2021] as the theoretical basis for all three methods. Table 1 shows the 12 quality indicators of the QUEST model, which we relied on in our study. In addition, the indicators are divided into three quality dimensions, stemming from Olesk et al. [2021, p. 7].

Table 1. Quality indicators of the QUEST model.

Trustworthiness and scientific rigour	Presentation and style	Connection with society
Scientific	Clear	Purposeful and targeted
Factual	Coherent and contextual	Impactful
Balanced	Spellbinding	Relatable
Transparent	Interacting with the audience	Responsible

3.1 Training analysis

Based on the QUEST model, we developed a science communication course in two methodological approaches. In the analysis, we focused on two aspects. First, we analysed the submitted assignments searching for the implicit presentation of QUEST indicators in the texts. Second, we analysed the reflection group interviews with the PhD students to see how they reasoned using the QUEST model in conducting their assignments. We tested this course on two groups of PhD students (N=14). The PhD students were part of a Horizon project on reproductive medicine. They were all second-year students from five different countries in Europe.

We named the groups *QUEST group* (N=7) and *practice group* (N=7) to distinguish them by the thematic selection of the teaching. The QUEST group had one lecture (90 minutes) explaining the QUEST model and its use in science communication practice. Then they had three lectures (3×90 minutes) on topics of newsroom practices (news values and news selection, communication with sources) and journalistic genres (news, feature, and opinion). The practice group had four lectures on newsroom practices and journalistic genres. All the lectures had activities in which the students had to reason the knowledge using the QUEST model. We highlight that in the practice group, we did not emphasise the QUEST model's role in science communication but instead had the students use it as a tool for reasoning their practice. After the lectures, students had two weeks to submit three assignments (1) a communication plan for disseminating their study, (2) a popular science article on one of their study results, and (3) a social media post. After submitting these assignments, they had to reflect upon the objectives of the submitted piece, explain the target audience to whom the text was aimed, and analyse their work using QUEST indicators

3.2 *Analysis of research applications and interviews*

In our study, we analysed science C&D activities of applied research applications financed through the Estonian Research Council and supported by the European Regional Development Fund in 2021–2023. We focused on the applications of two programs: (1) *RITA* — a programme that aims to increase the state's role in strategically managing research and the capabilities of research and development institutions in carrying out socially relevant research [Estonian Research Council, 2023b]. (2) *ResTA* — a programme that supports research and development, adding value to Estonian wood, food, and mineral resources industries [Estonian Research Council, 2023a].

We combined two qualitative methods to collect empirical material: thematic text analysis and semi-structured expert interviews. The audio files of the interviews were converted into text using a *web-based speech recognition program* [Olev & Alumäe, 2022]. For qualitative data analysis, we used *MAXQDA Analytics*.

We conducted 31 semi-structured interviews with stakeholders (scientists N=11, entrepreneurs N=3, scientific advisers at the ministries and government office N=9), and officials responsible for communication activities at the Estonian Research Council (N=8). One part of the broader interview concentrated on the twelve quality indicators and their meaning from the perspective of science communication intended for different target and stakeholder groups. The fair representation of entrepreneurs results from the fact that, despite the 13 interview invitations and repeated invitations, the entrepreneurs did not respond or refused to be interviewed because they could not comment on the communication activities of the research applications, as they had no contact with these activities. This can be treated as a result where entrepreneurs see their cooperation in applied research applications only as image-building benefits for their company, and science dissemination activities are considered rather than the task of researchers.

We also performed a qualitative document analysis for four types of working documents: (1) the conditions for the provision of support in RITA and ResTA programmes; (2) working documents of the communication activities of the Research Council (including brief overviews of both planned and implemented communication activities; lists of radio and television programs, video clips, as well as conferences and seminars and published articles in the media, etc.); (3) RITA's and ResTA's communication plans; (4) dissemination plans for research applications.

Analysing the documents of the ResTA and RITA programs, we abstracted the primary target and stakeholder groups and the activities aimed at them. We used the *stakeholder matrix* (Figure 1) developed by Aubrey Mendelow [Mendelow, 1991] to analyse communication activities by target and stakeholder groups.

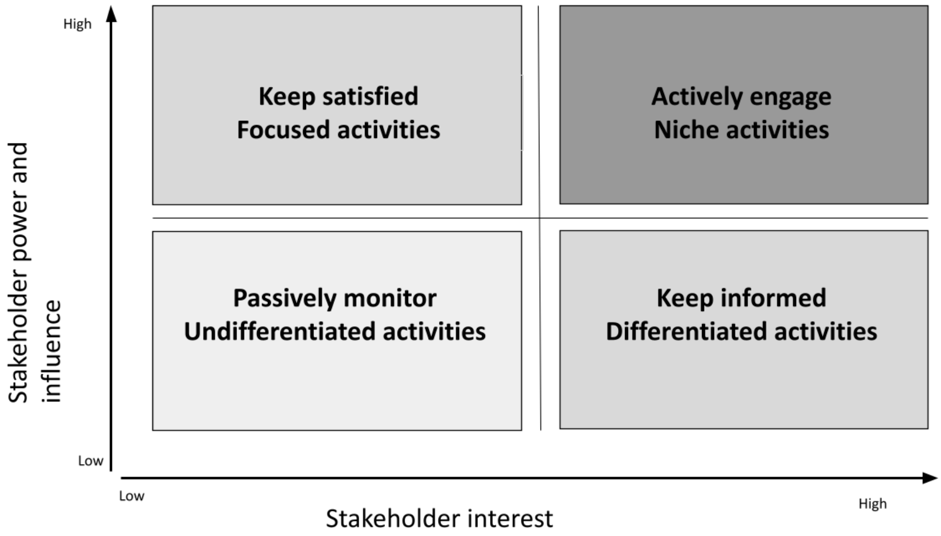

Figure 1. The stakeholder matrix is derived from Mendelow's [1991] approach to the differentiation of stakeholders.

The matrix includes both target groups (to whom the final impact should reach) and stakeholders (to whom communication activities are carried out directly). In the matrix, the power and influence of the stakeholder on the achievement of the goal is indicated on the vertical axis and the stakeholder's interest on the horizontal. The fields of the matrix indicate the nature of activities aimed at the target groups. In the matrix fields, we combined the communication activities within the research applications across different stakeholders to understand whether these activities cover all important target groups. Generally, the lower left field is the cheapest in resources (reaches many, but quite inefficiently), while the upper right is the most expensive in resources (reaches fewer, but more efficiently). The resource here is money, social capital, people's networking, and dedicated time.

Results

We present the results in the order of research questions, starting with insight into how PhD students reasoned and perceived the QUEST model's function in practice. This is followed by evidence of the QUEST model indicators in research applications and reasoning of it by scientists and science administrators.

4.1 *Reasoning and perceiving the QUEST model's function in science communication teaching*

Both groups were able to present all three assignments. Comparing the two groups, the practice group was more explicit in explaining the QUEST indicators in the texts. In the final reflection group discussion, the practice group students said they revised the indicators to analyse their work. Still, they needed to keep the indicators in mind while writing the assignments.

> *Did I look at the indicators while writing the article — of course not. But after submission, I thought about what I could have done differently. I could recall the "so what?" issue in the indicators, that the communication must have some impact on people. (Participant in practice group)*
>
> *I remembered that clarity was one of the central indicators because, without that, people will not understand what your research is about. (Participant in the QUEST group)*

The QUEST group was able to bring out the QUEST indicators concerning their submitted assignments but was explicit about not perceiving the indicators while writing the texts.

The reflection group discussion showed that the students perceived the QUEST indicators separately from their assignments and did not seek support from the QUEST model in the writing process.

> *Discussion in QUEST group:*
>
> *Participant 1: It gave a good fruit for thought for reasoning science communication, but it did not help to write the article.*
>
> *Participant 2: I agree that it is also relevant to realise why and for whom we communicate the results, but yes, it did not help much in doing the assignments.*

Therefore, the indicators functioned as a tool to reason the finished communication actions, not vice versa. This is a relevant finding as it shows that QUEST indicators support reasoning the C&D activities in teaching situations. Nevertheless, as the indicators were not used in the planning and writing process, it shows that the QUEST model was not seen as a helping tool.

This finding indicates that when PhD students are assigned to communicate and disseminate the results narrowly; the objective is to produce a publishable or useable piece of text (e.g., article, social media post or communication plan). From the analysis of one of the submitted assignments (a popular science abstract for social media), the difference between the two groups was mainly in the QUEST indicators the students focused on. The practice group assignments aimed at highlighting the results of the specific study, focusing on presentation and style (indicators like clarity, coherence, and context). As the students had to describe their potential target audience, they mentioned "the general public", "all women", and "the society", which according to the stakeholder matrix, categorises the undifferentiated activities relating to passive monitoring of the stakeholders as can be seen in the following extracts of two participants' assignment in the practice group:

> *Cells from the endometrium spear outside the uterus, and they affect the organ's function. For now, I'm studying some proteins that are found to be expressed in the development of endometriosis. The main question now is to study how these proteins may be involved in endometriosis during the pathogenesis of endometriosis. In my*

> *research, I look at the developmental programs. My model system is cow embryos. When a sperm meets the egg, there are some stages that are related to the MRNs are translated into proteins that are workhorses. As for IVF procedures, we can then predict how these developmental processes are going on. We can come up with more solutions for infertile couples.*

This result indicates that while the PhD students' goal was to communicate the results, the target groups became subsidiary. In the QUEST group, all participants focused on explaining the impact of their study, generalising the results and making a call for action. To deliver the message, several of them used storytelling techniques to make the text spellbinding and relatable for the audience — both QUEST indicators respectively in the presentation and style and connection with society domains.

> *Endometriosis affects 10% of women worldwide. This disease means that the cells from the endometrium spear outside the uterus, and they affect the organ's function. This disease causes chronic pelvic pain and problems with fertility. This is why research on diagnostics and treatment of endometriosis is relevant. While every young woman should get tested for this, my research is looking for the reasons that cause the disease on the genetic side.*

The previous extract from QUEST group participant's assignment illustrates with statistical fact why the object of research is relevant (impactful), what it does in the human body (relatable and scientific) and brings out the call to action for the target group (purposeful and targeted) wider goal of the PhD student's work (coherent and contextual).

The spellbinding storytelling also entailed an entrapment. Some assignments were entangled in engaging with the narrative but lacked the scientific and factual focus on specific research results, as can be seen from the extract of the QUEST group participant's assignment:

> *My work resembles what musicians do. A musician follows a core of notes that develops a show. Our core of notes is genome — my hair colour, my eyes. Also, the risk of diseases. The genomes can predict the female or male genes that are more likely to affect the fertility, early menopause or endometriosis.*

To sum up, these results can be elaborated to a real-life situation similar to compiling a C&D plan for a research application or writing a popular science article on a study's results in a research project. If scientists and researchers use the same tactics in communication activities, they may not perceive or will discard the QUEST indicators in the process.

4.2 *Evidence of the QUEST model indicators in research applications*

A large part of the scientific research is done on a project basis. Therefore, the science communication carried out within the framework of research applications is also growingly relevant. We highlight three main findings.

First, the documents that set the direction of science communication for research applications are detailed but mostly impractical or formal. The general objectives formulated in the fundamental documents of the RITA and ResTA programmes are very comprehensive. Programmes support strategic research and development activities — implementation of socio-economical interdisciplinary applied research needed by the state, building research capacities in different strategic fields, also developing cooperation between companies and research institutions. The communication plans of both programs are extensive, detailing the general goals of communication: what information is conveyed, which channels are used, what are the main messages, and who the spokespersons are; in addition, possible risks and problems are formulated. Those vastly clearly formulated goals remain too theoretical, so they practically do not help a researcher engaged in science communication. More important than formal requirements are the quality and impact of each communication activity. This has not been addressed in the program documents.

In some ways, the analysed documents relate to the different dimensions and indicators of the QUEST model, but this relation is still very indirect. The interviews revealed the need to improve the quality of science communication. Very comprehensive but general documents, bureaucratic requirements, and formal or impractical communication plans are of little help. In addition to them (or instead of them), situation-based and goal-oriented practical QUEST toolboxes for good scientific communication could be prepared. Applicable QUEST guidelines could help to craft and target the message for different audiences.

Second, the quality of science communication in research applications is significantly determined by the fundamental attitude towards science communication in general. Our analysis confirmed that the communication of research applications largely depends on the general attitude of the various stakeholders towards science communication as a phenomenon [Kara & Fischhoff, 2023]. The documents and interviews revealed that at the level of expert committees, research teams and their leaders, communication activities are often treated as a secondary activity or merely a formal section in the application or report (even if the importance of science communication was recognised). Experienced top scientists or innovative young researchers differed from this attitude by viewing public science communication as an organic part of their daily work. In the case of science communication being viewed as a formality, the activities lack quality and, in particular, clarity and purposefulness. A high quantity of activities are carried out but not explicitly targeted.

Third, the scope of science mass communication is as broad as possible, but the impact is negligible. Our research shows that the science communication activities of research applications are mainly aimed at the so-called mass audience. Since the focus is on the general public, target groups with essential social influence (for example, policymakers, entrepreneurs, etc.) are reached minimally. To involve and engage them, it would be necessary to do different activities, which are much better aimed, and more personal — it also means more dialogical or deliberative. This, in turn, requires more specific and professional science communication skills and resources.

4.3 Scientists' and science administrators' reasoning of the QUEST model's indicators in research applications

Nowadays, science communication aims not only to transfer knowledge to society or the mere popularisation of science but also to create meaning in society [Horst & Davies, 2021]. This broad view applies to both public and non-public and academic communication. The interviews revealed that in the case of RITA and ResTA research applications, in addition to the communication of facts, more expert assessments and interpretations are expected. That would help shape so-called informed decisions — including evidence-informed policymaking [Szüdi et al., 2022] — at different levels of society. This was particularly evident in the view of the scientific advisers of the ministries.

Science communication as a field has developed and expanded significantly. The so-called cluster crises of recent times have probably played a big part in this. However, in any case, due to the expansion of responsibilities and functions, the issue of the quality and reliability of research communication, in general, has become more acute.

Although the QUEST model is intended to be non-hierarchical, in our study, we asked the interviewees to rank in order of importance the twelve indicators that determine and measure the quality of scientific communication. We also asked for a brief explanation of the resulting order of different indicators. The results revealed that the three areas presented in the model are almost equally important. Looking at the data of the top three indicators formed by field, there are minimal differences: *presentation and style* — 39 mentions in the top three; *connection with the society* — 37 mentions in the top three; *trustworthiness and scientific rigour* — 36 mentions in the top three.

Emphasis has been placed on the top three, as the interviewees admitted that ranking them in order was the clearest or easiest and most justified (some interviewees even limited themselves to organising the top three). Starting from the seventh, the ordering of indicators was generally more random or vague. Many interviewees also pointed out that the ranking of QUEST indicators is more instinctive than conscious, which is also natural, because neither researchers, entrepreneurs, nor scientific advisors are communication experts (except perhaps experienced distinguished scientists, whose attitude towards scientific communication is very professional). Table 2 shows the order of importance of the QUEST indicators based on the interviews.

Based on the interviews, the top three form a model that reflects all areas of the original QUEST model. However, based on this model, the most critical indicators of a high-quality science message are: (1) *clear* (2) *scientific* (3) *purposeful* and *well-targeted*. At the same time, the interviewees admitted that these characteristics have generally also been considered in their communication activities.

Table 2. Ranking of the QUEST model indicators based on semi-structured interviews.

	trustworthiness and scientific rigour				**presentation and style**				**connection with the society**			
	Scientific	Factual	Balanced	Transparent	Clear	Coherent and contextual	Spellbinding	Interacting with the audience	Purposeful and targeted	Impactful	Relatable	Responsible
1.	6	1			4	1	5		8	3	1	3
2.	7	4	1	1	6	1	3	2	5	3	3	2
3.	4	7	3	2	8	2	5	2	3	2	3	1
	17	**12**	**4**	**3**	**18**	**4**	**13**	**4**	**16**	**8**	**7**	**6**
	36				**39**				**37**			
4.	2	1	2	1	1	3	2	4	5	3	3	2
5.	2	4	3	2	3	1	2			2	2	1
6.	1	1	1	1	2	3		1	3	6	3	3
7.	1	1	1	2		3	1	1			1	6
8.	1		2	5		5						1
9.		3	3				1	2	1	2	1	1
10.			2	1		1	1	5		3	2	
11.		1		3				3			3	
12.	1		2	1			5	1				3

Clear — is described in the QUEST model as an indicator that the language used in the texts is comprehensible. Communication has a clear focus and highlights central messages. When evaluating the indicator, the following are considered: (1) Is the information presented in easy-to-understand and clear language? (2) Are the scientific terms used sufficiently explained? (3) Are the central messages highlighted? [QUEST, 2021]

Regarding clarity, it was pointed out in the interviews that: "*. . . the message must be short and clear to reach the target group. The correct and good message in a confused form does not reach the place. In the best case, the information is ignored, but in the worst case, it is misused.*"

In addition, as revealed in an interview, clarity emerged as a problem: "*. . . This is a huge problem for us, I think, the ability to formulate our science in a clear way that people can understand; or they do not bother, they do not consider it necessary to explain in a comprehensible way to an ordinary person — this can be largely reason to society's scepticism about what these scientists are doing.*"

Scientific — as an indicator of the QUEST model, it points out that good science communication relies on credibility, rigorous scientific knowledge and sources. References to scientific sources are included. When evaluating the indicator, the following are considered: (1) Is the presented information scientific? (2) Is the source of scientific knowledge identifiable? [QUEST, 2021]

The interviews consistently stated that scientific knowledge is: "*…undoubtedly the most important indicator — it is what distinguishes science communication from any other communication.*"

Science-based information was considered a strict unwritten rule or prerequisite for science communication: "*…Science-based message seems like dogma for science communication. If we do not have a strong scientific basis, then scientific communication would not be possible.*"

Purposeful and Targeted — as a QUEST indicator, communication has a clearly defined purpose, knows its audience, and is adapted to address the desired target groups. When evaluating the indicator, the following are considered: (1) Is it clear what the purpose of the communication is and who the target groups are? (2) Do the selected format, style, and other communication characteristics support achieving the goal? [QUEST, 2021]

This indicator was named one of the critical issues of good science communication. In the case of purposeful and well-targeted science communication, it was highlighted in the interviews: "*…There should be a targeted message for each audience, and that well-understood language should also be used so that the information reaches the audience.*"

A semantic question arose with the term "impactful": "*…I perceive impact differently, that it is a bit like lobbying, that you want to influence someone. The only impact of science communication is that people become aware of these things and understand better what is being done and why. However, tilting them to one side or the other should not be the goal of science communication.*"

In addition, the "balance" was seen as an indicator of good journalism rather than necessarily related to science communication. It also emerges from the interviews that the "spellbinding" as a QUEST model indicator is understood either as one of the most crucial measures or, on the contrary, as the least relevant, depending on whom the interviewee considered to be the leading target group — either scientists or the general public.

It was consistently recognised in the interviews that good scientific communication must consist of all these indicators. Therefore, compiling the ranking was a rather difficult task for the respondents.

Looking more broadly at the results that emerged from the interviews, the meaning of the QUEST indicators is generally well understood. There were a few minor exceptions when there was a specific inconsistency with some indicators (for example, with the term "impactful"). In general, all indicators were considered necessary. The model works even though not all indicators are followed or applied in every communication activity.

Our study shows that the interviewees considered the quality dimensions formulated in the model and all twelve quality indicators relevant to science communication. These indicators are generally considered, although it can often be intuitive — primarily if the responsibility for science communication is assigned to researchers who do not have communication-specific competencies (which is expected because their main work is not public communication). This was acknowledged by several interviewees, who took the task as a fun game and ranked the quality indicators purely by gut feeling — the QUEST indicators were approached intuitively rather than deliberately.

Conclusions and discussion

This study tested the possibilities and obstacles of using the QUEST model [Mannino et al., 2021; Olesk et al., 2021] in teaching science communication to PhD students and applying the model in planning and conducting C&D activities for research projects. While this study tested the applicability on PhD students, we argue that the model can be used in all levels of higher education science communication training. We highlight three central findings: (1) in science communication training of PhD students, the QUEST model functions better when used as a supportive tool for reasoning and perceiving communication activities. (2) formal communication requirements for research applications create an "Excel table syndrome"; (3) the deficit-based communication model stemming from the mediatisation concept [Hepp, Breiter & Hasebrink, 2018] is aimed at disseminating research results and does not support dialogical and deliberative science communication. Thus, theoretical foundations and practical approaches to science communication must be reconsidered.

In our analysis, we saw that to reach influential target groups (e.g. policymakers, entrepreneurs, etc.), the media logic alone is not helpful — more personal ways and different tools of science communication must be found. The findings of this study show that if the purpose of communication has not been clearly defined, its possible impact has not been predicted. Suppose the main goal is to disseminate as many research results as possible. In that case, many resources are spent on many communication activities with a large audience but with little impact. In an environment oversaturated with information, the efficiency and quality of science communication becomes increasingly important than its quantity.

Our study indicated that the science communication activities lack clarity and purposefulness when viewed as a formality — a tick box in an Excel table — of research application and not an organic part of the actual activities of a project. It means that science communication activities with "Excel table syndrome" do not contribute to their quality or impact. When science is increasingly needed for more sustainable societal developments, it is also necessary to ensure that science communication is as effective and reliable as possible. These indicators distinguish science communication from modern (hyper-)information noise. Therefore, quality- based tools for science communication are also necessary.

Funding organisations can help change the value stream of science communication culture [Kessler et al., 2022; Palmer & Schibeci, 2014] if grant requirements are not formal and would prefer actual dialogue-based strategic science communication activities. From the beginning, it should not be the amount of dissemination of scientific information but its impact and quality that should be relevant. Science communication should mean real-life activities to avoid the "Excel table syndrome" and to reach all important target groups.

The "Excel table syndrome" is probably a broader problem (potentially at the level of various research applications of the EU research initiatives). However, further empirical research is necessary to elaborate on these findings.

Our interviews revealed that researchers use quality indicators in science communication, but this is relatively intuitive. Good science communication could be more intentional or strategic and aware of goals. The aim is to consider how the resources (financial means, time, and human resources) necessary for science communication would be used as efficiently and purposefully as possible. Besley and Dudo [2022a] describe how the fundamentals of strategic communication — e.g. audience analysis, goal setting, and message testing — could be used to increase scientific communication quality and efficiency [Besley & Dudo, 2022b]. Our study acknowledged that it is possible to make science communication more effective and strategic if the stakeholder matrix [Mendelow, 1991] is purposefully used to define specific activities by target groups and the possible channels to reach them. In addition, the QUEST model's quality indicators could help to choose the best possible format and style for delivering the message to specific audiences.

The QUEST model has been designed and works as a practical toolbox or framework for supporting or ensuring quality in science communication [Olesk et al., 2021]. All quality indicators are vital, but the QUEST model formed from the indicators ranked by the interviewees can be helpful. The model reflects all quality dimensions — trustworthiness and scientific rigour, presentation and style, and connection with the society — of the original model. However, based on this model, the most critical three quality indicators (from 12) for good scientific communication are that the message would be: (1) clear; (2) scientific; (3) purposeful and well targeted.

Since the 1960s, when the so-called deficit model as a concept of natural science education was formulated, and from the 1980s, when it shifted to the paradigm of the public understanding of science [Kessler et al., 2022], science communication has been shaped by a particular value stream of public knowledge deficit (and other deficits) in science communication culture. Our study confirms that the so-called deficit model still applies to a very significant extent in science communication. The mental model has been deeply embedded in scientists' thinking, and it still dominates when communicating with non-scientific audiences or the wider public [Besley et al., 2017; Davies, 2008; Reincke et al., 2020].

The deficit model is mainly built on the quantity of scientific information or so-called mass science communication. Based on this, more scientific knowledge should be communicated to more people, although more knowledge does not mean more trust in science or better decisions [Kara & Fischhoff, 2023]. We also see that the deficit model is closely related to the advanced (deep) mediatisation [Hepp et al., 2018] processes of science — the media (also new media) is a key factor in the deficit model as the primary channel for mediating science and to fill the knowledge gap. Nevertheless, despite its broad audience, media-centric science communication is only one specific and quite limited part of science communication [Olesk et al., 2021]. Media logic trap can also be one of the reasons why dialogue-based scientific communication does not work and why essential target groups are not reached [Jonsson, Brechensbauer & Grafström, 2022].

The deficit-based communication model, parallel to the mediatisation concept, has been firmly aimed at disseminating research results, favouring the formation of the current patterns of science communication. Contemporary science communication needs a coherent paradigm shift in theory and practice. That concerns all communication partners involved, including science administrators, who are vital in implementing the change towards science communication to be better related and relevant to society. Also, science communication practitioners need theoretical support in real life to move beyond the limitations of different deficit concepts.

Scientists and science communicators are ready to contribute to quality and effectiveness in more strategic science communication ways. At the same time, the lack of professional communication skills is recognised as an obstacle. This is also normal because we cannot assume that every researcher should also become an expert in professional science communication who can make strategic communication choices [Besley & Dudo, 2022a]. Therefore, developing evidence-based toolboxes for supporting quality in science communication is particularly necessary.

Brüggemann et al. [2020] have noted that we now face the challenges of post-normal situations where different contemporary societal necessities should be met. In this context, science communication is becoming even more vital because, in chaos, the world needs scientific knowledge to dissolve or balance the messes around us. In addition to communicating facts, more open conversations about science and expert assessments or interpretations are required to make sense and meaning from science for society [Horst & Davies, 2021]. A mixture of modern dialogue or deliberative and risk communication models could help. However, there have been few studies of strategic science communication, and the theoretical approaches still need to be thoroughly argued.

As a research field, science communication is rapidly growing. We have reached a situation where theories have developed enormously but have yet to be implemented appropriately. Although the deficit model — filling the knowledge gap — works in its way, and science has become quite popular, but — to make a real difference, — is not enough. Science communication theoretical approaches have supported filling society's knowledge gap. At the same time, the information-saturated world needs something different: open social conversations around science [Bucchi & Trench, 2021] and making sense of evidence [Mayne et al., 2018]. We argue that theoretical foundations and practical approaches to science communication should be reconsidered and reformed, potentially sifting from mediatisation-based to deliberative communication-based foundations.

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Authors

Ebe Pilt is a PhD student and junior research fellow in science communication at the University of Tartu, Estonia. Her main research interests are the practical mediation and remediation processes of scientific knowledge in the current context of mediatisation and the framework of dialogic or deliberative concepts. Ebe has been working in the field of science communication for many years as a chief communication specialist, as well as an editor and a (science) journalist.

ebe.pilt@ut.ee

Marju Himma-Kadakas is an Associate Professor of Journalism Studies at the University of Tartu, Estonia. Her research combines studies on newswork and journalistic skills. Marju's research also embraces the intersection of information disorder and science communication in relation to journalistic practice. She also has 12 years of experience as a cross-platform science journalist.

marju.himma@ut.ee

How to cite

Pilt, E. and Himma-Kadakas, M. (2023). 'Training researchers and planning science communication and dissemination activities: testing the QUEST model in practice and theory'. *JCOM* 22 (06), A04. https://doi.org/10.22323/2.22060204.

ISSN 1824-2049. Published by SISSA Medialab. jcom.sissa.it