Exploring Perceptions of Credible Science Among Policy Stakeholder Groups: Results of Focus Group Discussions About Nuclear Energy

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Abstract

How do different stakeholder groups define credible science? Using original qualitative focus group data, this exploratory study suggests that while nuclear energy stakeholder groups consider the same factors when assessing credibility (specifically, knowledge source, research funding, research methods, publication, and replication), groups differ in their assessments of what constitutes expertise, what demonstrates (or reduces) trustworthiness, and the relative prioritization of expertise versus trustworthiness. Overall, these results suggest it is important for science communication to consider audience-specific credibility, and raise questions about the potential impact of both funding sources and predatory journals upon the perceived credibility of scientists.

Key Words

Credibility, expertise, stakeholders, nuclear energy

Introduction

Since the 1990s, many countries have experienced an "identifiable movement" towards evidence-based policymaking, including the emergence of organizations promoting evidence use in debate and decision-making (Lunn & Ruane, 2013, p. 2). This normative ideal of evidence-informed decisions faces numerous challenges: evidence may be complex, incomplete, or even contradictory, and perceptions of what "counts" as appropriate evidence are often contested, as the

"demarcations between science and non-science are no longer evident" (Nowotny, Scott, & Gibbons, 2001, p. 29). Although the production of science is intended to be as objective as possible, in reality both the production and use of science includes considerable subjectivity, including individual interpretations of what is credible.

Source credibility refers to an audience's judgment regarding the "believability" of a source (O'Keefe, 1990). Individuals may differ in such assessments; as Rallis (2009) explains, "credible evidence is what the relevant communities of discourse and practice accept as valid, reliable, and trustworthy" (p. 171). Just as trust is "given" from individuals to other individuals, organizations, or systems, credibility is ascribed by audiences to research products, rather than being an inherent characteristic of the research itself (Bentele & Seidenglanz, 2008).

In policy and public debate, there are numerous stakeholder groups, including scientists, industry, government, and public/societal groups. Differences in interests, values, and capacity suggest these groups may vary in their understanding of what is, and is not, credible evidence. Understanding how different stakeholders interpret credibility has the potential to aid science communication. Bauer, Allum & Miller (2007) argue that three paradigms of science communication continue to inform the field: science literacy, which focuses on increasing public knowledge; public understanding of science, which emphasizes both increasing knowledge and improving attitudes towards science; and science and society, which emphasizes building public trust and confidence in science. Information on how different audiences assess research credibility, and why they assess credibility in the way that they do, equips researchers to anticipate, appreciate, and account for audience-specific credibility concerns in science communication efforts.

The potential for differing stakeholder credibility perceptions also speaks to the role of science and expertise in policy decisions. Wynne (2008) argues that "public concerns and meanings legitimately differ from expert ones (and among themselves very often, too), and that *every such citizen* is in principle a legitimate participant in what should be the deliberative negotiation of such public meanings" (p. 27, emphasis in original). In contrast, Collins & Evans (2007) seek to demarcate political (non-science) and technical (science) decision-making phases, arguing that more narrowly defined expertise should have greater weighting on technical matters: "experts should obviously have a relatively greater input when their results are more reliable" (p. 135). Stakeholder differences in perceptions of expertise may inform their opinions regarding the legitimacy of different policy actors.

This qualitative research study was conducted to inform science communication by providing an analysis of different stakeholder groups' views towards research credibility. Using nuclear policy stakeholder groups as a case study, we consider the following research question: How do different actors vary in their understanding of what constitutes credible evidence? As nuclear energy may present a unique case, this research is exploratory in nature.

Source credibility and research utilization in policy debate and decision-making

In academic literature, source credibility generally has two key dimensions: expertise and trustworthiness (Hovland, Janis, & Kelley, 1953; Sprecker, 2002; Pornpitakpan, 2004; Callaghan & Schnell, 2009; Lombardi, Seyranian, & Sinatra, 2014). Perceived expertise captures the audience's evaluations of the source's ability to speak authoritatively on a topic. Perceived trustworthiness captures the

audience's evaluations of the source's honesty and integrity, for example, assessments of the researcher's biases.

Source credibility is understood to have considerable influence on the use (and non-use) of scientific information in opinion formation and decision-making, as "source credibility alters the priority people assign to various arguments and emphasizes a certain line of interpretation as valid, relevant, salient and believable" (Callaghan & Schnell, 2009, p. 13). Research suggests that individuals can process information either systematically or through heuristics (Bråten, Strømsø, & Salmerón, 2011), and that people "usually turn to simple heuristics, such as whether or not they like or trust the source, when evaluating a message" (Goren, Federico, & Kittilson, 2009, p. 806).

The importance of heuristics such as source credibility may be greater in areas with conflicting or uncertain scientific information (Peters, 1992; Corley, Scheufele, & Hu, 2009) or when the individual has either low capacity (for example, limited knowledge on the specific topic) or low interest (Bråten, Strømsø, & Salmerón, 2011). Heuristic processing is thus highly relevant in complex policy fields, including more scientifically-oriented policy fields, as individuals often rely on the information and knowledge from other actors, such as scientists or government, to assess risks and benefits and to eliminate uncertainty (Siegrist & Cvetkovich, 2000).

While various groups (sources) attempt to frame issues, the persuasive impact of the frame varies with source credibility (Druckman, 2001), and people's attitudes towards sources contributes to whether people accept scientific innovations (Malka, Krosnick, & Langer, 2009). Indeed, research indicates that individuals will consider source credibility before actual message content when

processing information, particularly if the individual has low involvement with or interest in the issue (Chaiken & Maheswaran, 1994; Callaghan & Schnell, 2009; Brewer & Ley, 2013), and that individuals' levels of trust in other actors can influence their perceptions of the overall policy issue (Siegrist, Cvetkovich, & Roth, 2000) as well as their perceptions of safety and risk (Robins, 2001). There is reason to expect that credibility perceptions are relevant to attitudes regarding nuclear energy, the topic of our case study, as studies suggest that both knowledge (Costa-Font, Rudisill, & Mossialos, 2008; Greenberg & Truelove 2010) and trust (Sjöberg, 1999, Viklund, 2003, Siegrist, Gutscher, & Earle, 2005) may be relevant to nuclear risk attitudes.

Survey research finds that university scientists are often perceived as more credible, competent, and/or trustworthy than other sources (Sprecker, 2002; Bickerstaff, Lorenzoni, Pidgeon, Poortinga, & Simmons, 2008; Fiske & Dupree, 2014; Matthews, 2015). The perception of scientists as credible has implications for policy debate; for example, trust in scientific experts is a heuristic commonly used by members of the public when forming their perception of risks as well as their general attitudes toward emerging technologies (Liu & Priest, 2009: 12; Lachapelle, Montpetit, & Gauvin, 2014). Scientists, then, may be in a unique position to influence public debate, as Gauchat (2012) suggests: "In its legitimation role, the scientific community leverages its credibility and technical expertise to assess and certify social policy and other institutional practices" (p. 168).

Credibility perceptions can also influence the use of evidence in policy decision-making. Research suggests that characteristics related to source expertise, including researcher/research unit and research methods, influence whether a source is considered in decision-making (Weichselgartner & Kasperson, 2010; Lester

& Wilds, 1990; Head, 2010; Webber, 1987; Dobrow, Goel, & Upshur, 2004). If decision-makers perceive scientific research credibility to be high, this may increase the likelihood of research utilization, while low perceptions of scientific credibility risk undermining research utilization.

Why stakeholder groups may vary in perceptions of source credibility

Research demonstrates the importance of values to perceptions of science. For example, Gaskell et al. (2005) and Priest (2006) find considerable variation in the values that influence public attitudes regarding risk issues (specifically, gene technologies) and decision making; for important segments of the general public, concerns regarding ethics and morality are prioritized over risk-benefit perceptions. In their work on "cultural cognition", Kahan, Jenkins-Smith, & Braman link values to credibility perceptions: "Individuals more readily impute expert knowledge and trustworthiness to information sources whom they perceive as sharing their worldviews and deny the same to those whose worldviews they perceive as different from theirs" (2011, p. 149-150). In addition to values, epistemology (beliefs about knowledge) matters: Barzilai & Zohar (2012) find that epistemic thinking influences how individuals evaluate sources, and Bromme & Goldman (2014) argue that epistemological differences can influence how scientists and the general public understand science information.

Two key lessons can be drawn from this body of literature: first, the population contains multiple subgroups with differing cultural values and epistemic stances; and second, these cultural values and epistemic stances have relevance to perceptions of science and credibility. Similarly, in the marketing literature, an

underlying premise is that market segments (population subgroups) have differences in personal and attitudinal variables that may predict consumption-related outcomes (Smith, 1956; Tynan & Drayton, 1987).

Drawing on existing research, we might expect stakeholders to vary in at least three ways. First, groups may differ in their assessments of source expertise; this may reflect differing capacities to assess researcher training and methodologies, and/or motivated reasoning, as individuals may be inclined to ascribe expertise to evidence that is consistent with pre-existing beliefs (Kahan, Jenkins-Smith, & Braman, 2011) or to positions/beliefs held by identity groups with which they identify (Kahan, 2011). Second, different audiences may disagree on what factors contribute to or undermine source trustworthiness. And third, it is possible that groups may diverge in their emphasis on questions of expertise and trustworthiness; we cannot assume these dimensions are weighted equally in individuals' minds.

To date, empirical studies comparing how different stakeholder groups perceive research credibility are uncommon. Two studies suggest scientists and nonscientists alike feel that university scientists have greater credibility than do other sources (e.g., NGOs, government and industry) (Lach, List, Steel, & Shindler, 2003; Rivers, 2012). Lach, List, Steel, & Shindler's study (2003) on research credibility found that scientists prioritize research methodologies and researcher reputation, while nonscientists (government and citizens) prioritize the practical applications of research and effective communication. Yamamoto's study (2012) of credibility perceptions found that scientists emphasized professional standards, whereas citizens emphasized values and assumptions underlying research.

Other studies have considered stakeholder groups individually. Research suggests that laypeople often infer source credibility from textual features (Thomm & Bromme, 2012) and have the ability to discern relevant expertise to a scientific topic (Bromme & Thomm 2016). Studies of policy officials suggest they perceive academic researchers to be more credible than other sources due to their neutrality (Lorenc, Tyner, Petticrew, Duffy, Martineau, Phillips, & Lock, 2014), and place emphasis on peer review and expertise when assessing scientific evidence sources (Young, 2014). Schapira, Imbert, Oh, Byhoff, & Shea's study (2014) of medical patients found that both expertise (research methods and consistency of results over time) and trustworthiness (perceived conflicts of interest related to funding sources) are relevant to credibility perceptions.

In summary, because credibility is a subjective and relative characteristic ascribed by the audience, differing audiences can have varying perceptions of the credibility of a particular source or body of knowledge. To date, research that considers a range of actors, including industry, has been limited (Kinchy & Kleinman, 2003).

Methods

Context. Our investigation of research credibility perceptions across stakeholder groups was part of a research program on the communication and use of scientific research in nuclear policy in Saskatchewan, Canada. Nuclear policy is an ideal case for examining our research questions: the science involved is highly complex, the topic is both contentious and salient, and stakeholders include scientists, industry, government, and the public. Saskatchewan is active in uranium

mining; while the province does not generate nuclear power, nuclear policy is highly salient, as both nuclear energy and nuclear fuel waste storage have been policy considerations in recent years.

Qualitative approach. Our aim was to generate new insights about credibility across stakeholder groups. Qualitative research is particularly useful in generating new insights and arriving at new ways of thinking about existing research problems; it is also appropriate in contexts like ours where existing measures may not capture the phenomena of interest (Patton, 2002).

As the research question considers how different stakeholder groups vary in their understanding of credible evidence, focus group methodology is particularly valuable: the social aspect of focus groups promotes information sharing (Onwuegbuzie, Dickinson, Leech, & Zoran, 2009) and encourages "research participants to develop ideas collectively" (Smithson, 2000, p. 116). Focus groups are well suited to complex issues that require a holistic explanation of experiences in order to be understood (Carey & Asbury, 2012), and perceptions of credibility within nuclear energy debates are complex. Focus groups are an excellent method for identifying similarities and differences among people (Stewart, Shamdasami, & Rook, 2009), which is integral to our research question. Further, focus groups provide participants the opportunity to frame issues in their own words, allowing for more nuanced understanding (Kotchetkova, Evans, & Langer, 2008). Focus groups do not seek representativeness; rather, lessons gathered can inform future studies that emphasize representativeness and generalizability. Focus groups have previously explored phenomena across a range of science communication studies, including

biotechnology and genomics (Dijkstra & Gutteling, 2012), stem cell research (Vicsek, 2011), and renewable energy (Silk, Hurley, Pace, Maloney, & Lapinski, 2014).

Sample and recruitment. We applied non-probability sampling in this study. Our sampling goal was to characterize the perspectives of four stakeholder groups: scientist (defined as researchers working within an academic setting), industry (individuals working within the private sector), government (non-elected public servants), and community (individuals active in environmental groups with a particular interest in nuclear issues). We recruited respondents through email and telephone contact. To generate the initial sampling frame for each stakeholder group, the research team brainstormed a list of people and organizations to contact who would be sure to have experience with the topic area within a nuclear context. We then used snowball sampling to identify additional respondents. All individuals had experience with nuclear and/or energy policy or research.

To ensure frank discussion, we organized focus groups by the four stakeholder groups. The focus groups were held in November and December 2014. Because our study is exploratory, a smaller number of focus groups is acceptable (Carey & Asbury, 2012). Group sizes ranged from five to seven participants, with 25 participants in total (scientists: 1 woman, 6 men; industry: 3 women, 4 men; government: 0 women, 5 men; community: 4 women, 2 men). Given the small provincial population, and even smaller populations within subgroups, we did not collect nor do we report detailed demographic information. Each of the focus groups represented a range of ages. As most participants were recruited for their experiences as paid professionals, the income and education levels of most participants was higher than the general population. While the community group

had a greater range of income, occupation, and education levels, all were engaged extensively in the debates around the nuclear sector, such that their level of scientific knowledge of nuclear likely exceeded the average citizen.

We held three focus groups in a university campus meeting room, and one focus group (with government) in a rented meeting room. We offered all participants refreshments and snacks, and reimbursed the community focus group members for transportation costs. While recruiting participants, we framed the research project as a study about evidence in nuclear policy and decision making; our invitation letter stated, "Our project is examining communication processes between evidence producers (e.g. academia) and key audiences (e.g., policy officials, industry officials, community groups). We are conducting focus groups to investigate the current use of evidence by key audiences and to identify areas for improved evidence communication strategies." We obtained university ethics approval for the research study and written informed consent from all respondents.

Moderation and guide. We conducted the focus groups in English. A moderator ensured the discussion flowed smoothly, that all topic areas were addressed, and that each participant was given opportunity to speak. The moderator holds a PhD in the social sciences, and has extensive research experience in both nuclear issues and qualitative methods. Three other researchers with training in qualitative methods participated in the data analysis; two hold PhDs in the social sciences, and one is a social science PhD student.

Literature on scientific knowledge utilization informed the focus group guide. The guide began with a discussion of general perceptions of credible scientific evidence: "What do you consider credible scientific information? What are some of

the characteristics of credible scientific information? Does it make a difference who produces the scientific information? If so, how and why?" The emphasis of the focus groups was on science generally, but because participants were explicitly invited for their involvement in the nuclear sector, discussions about science naturally centered around nuclear and nuclear energy. Subsequent questions explored factors related to evidence use, a theme that is not explored in this paper.

Analysis. We digitally recorded the focus groups and transcribed them verbatim; the exception was the government focus group, as one respondent did not consent to recording. For this focus group, two researchers typed notes in real time and we compared the two sets of notes for accuracy. In all transcripts, we concealed the identities of respondents to protect confidentiality. Our coding identified respondents with both individual numbers and a letter designating the focus group (S=scientist, I=industry, G=government, C=community; e.g., S4, G2).

Using NVivo software to assist in data management, we subjected transcripts to thematic analysis, "a method for identifying, analyzing and reporting patterns (themes) within data" (Braun & Clarke, 2006, p. 79). To be identified as a theme, the subject matter must have presented itself as a repeated pattern, both within and across participants' narratives. Whether something is considered a pattern depends not only on the frequency of repetition, but also whether it is connected to the research question (Braun & Clarke, 2006). Therefore, as we analyzed the data for themes, we focused on text that helped us better understand stakeholder credibility perceptions. We applied thematic analysis in order to reflect participants' reality and experiences.

We analyzed the transcripts for primary and emergent themes. Primary themes were expected based on the literature (called "theoretical thematic analysis", Braun & Clarke, 2006). Emergent themes transpired in the focus groups; these were identified by all members of the research team, who were engaged in the focus groups as observers, and through the formal coding process (by one research team member and one independent coder). This study is strengthened because we involved multiple perspectives in the analysis and interpretation of the data (called "investigator triangulation," Patton, 2002, p. 247).

Results

Five major themes emerged from the data; all are perceived aspects of credibility relating to expertise and/or trustworthiness. According to focus group respondents, the credibility of research varies with knowledge source, research funding, research methods, publication, and replication. The first four themes are primary themes that we anticipated based on our review of existing literature; the fifth theme is emergent because the research team identified it during analysis.

Knowledge source. Participants identified the knowledge source – be it an individual scientist or group of scientists, or an organizational source – as a critical component of credibility. All four groups asserted that a general hierarchy of research credibility exists, with academic research seen as the most credible, industry research as the least credible, and government and non-governmental organization (NGO) research falling somewhere in between.

The scientists took the most detailed view, and were particularly focused on the individual researcher's reputation and training. Stated one (S5), "I look where

they're from, I look at what they do. If someone is talking about nuclear energy and they have a degree in something that's completely unrelated, then I'm going to look a little bit harder about where that background comes from."

Industry respondents made a distinction between whom they deemed as credible and whom they felt the general public perceived to be credible. For their own purposes, they focused on the individual researcher, with an emphasis on reputation. One industry respondent (I5) stated, "there's certainly legitimate world experts" and that different industry actors "recognize the same group of experts"; this viewpoint was broadly shared within the group. While the industry respondents did not feel that industry-generated research was necessarily less credible than other research, there was widespread acknowledgement that such perceptions are prevalent among the general public due to beliefs about trustworthiness. Some respondents argued that medical doctors in particular enjoyed a high level of public credibility, again due to perceptions of trustworthiness, even if such credibility might not be warranted with respect to actual subject area expertise.

Government respondents also distinguished between their own and the public's credibility perceptions. For their purposes, they noted that academic scientists are seen as being the most credible, but beyond this spent little time discussing knowledge source, other than to note that knowledge sources must be "independent and trustworthy" (G4).

Community respondents were emphatic that industry research is not credible due to issues of trustworthiness. This declared lack of trustworthiness was linked to the perception that industry would not publish any research results detrimental to its own interests including profit or reputation.

With respect to non-industry research, community respondents articulated the difficulty in reconciling competing research findings, which makes it hard for them to trust the findings. Stated one respondent (C4), "if you find something that is making one conclusion, we're taught to find a source that makes another conclusion. So now you've got two sources, two different conclusions about the same topic. So which one do you go with, which one do you think is true?" The fact that science can point in different directions pushed some community respondents to consider non-scientific sources (e.g., NGO material, non-academic/government/industry websites) to be the most credible knowledge sources.

As Lach, List, Steel, & Shindler (2003) found that knowledge source is a factor in scientists' credibility perceptions, we classify knowledge source as a primary theme.

Research funding. Respondents across the four groups spoke directly about research funding as a component of credibility. As anticipated, the issue of funding sources invoked a range of responses. In the government and industry focus groups, respondents spoke of how their organizations see the funding of university researchers as valuable to their operations; specifically, in both groups, respondents spoke to the benefits of accessing university scientists' expertise to address specific questions. One industry respondent (I6) explained, "from time to time we come across gaps in [the available published] knowledge. […] typically what we'll do is then partner with a research institute or a university to work on those specific problems, where those gaps exist." In the words of a government respondent (G4), "If we have a really difficult problem we contract out."

While these relationships are clearly beneficial to government and industry, the respondents felt that the academic scientists also benefited; an industry respondent (I6) argued that there is the opportunity to "get it out and published and peer reviewed," while a government respondent (G5) stated simply, "It suits the academics in the face of funding limits." That being said, participants acknowledged that such contract research is not sustainable, as such research contracts and collaborations "tend to be fairly specific and not ongoing" (G5).

While industry and government respondents spoke of benefits, all groups mentioned that industry or (to a lesser extent) government funding reduces perceived credibility. Community respondents in particular voiced overarching concerns about funding sources; stated one (C2), "I think the funding of the project can have quite an influence and it's important to know who paid for the research." Echoed another (C6), "To me, the idea of who is paying for the research is probably one of the things that I want to know right away."

The scientists argued that such public concerns mean that researchers have to be highly transparent in their activities. Stated one (S5), "[Credibility] relates a bit to funding, if you're being funded by the nuclear industry, then that transparency is important for your results to be credible. Even though it has the trappings of scientific, there will be doubt in people's minds depending where your funding comes from." Another (S3) replied, "So I face this, because my research is supported by the oil sands industry. So everything I do, I'm incredibly transparent about what I'm doing." To this, the first scientist stated, "You want to make sure that people aren't saying, 'oh, you're one of those guys'."

For many of the scientists, transparency and the scientific peer-review process serve as mechanisms to protect against such biases. In the words of one (S7),

> When you do any research, any message, any fact that is published, reported, as scientific evidence, [you] must be transparent irrespective of who is the funder of the researcher. It may be the oil industry, some nuclear industry, or even a green public organization, whoever. .... it doesn't matter for whom do you work if you're an honest scientist, you're just making your science honestly, irrespective of the source of funds. In an ideal world, I mean. Your conclusions must not depend on the funding source. …. That's why there is scientific community that should check the results according to a very clear [standard]… and the most detail in description of your experiment or the way you come to the conclusion, the better for your peers.

Given this, it is not surprising that the scientists emphasized training, methods, peer review, and research reputation, as opposed to funding, as key determinants of credible research.

Government and industry respondents identified an important limitation to achieving research transparency through the peer review publication process: concerns regarding confidentiality and non-disclosure. As a government respondent (G3) explained, "One of the main things that affects collaboration is the requirement for academics to publish their results. Industry and government often don't want this. [Governments] feel issues are security related." An industry respondent (I5) provided further comment on this point: "I would always say that any time we access

the scientific community, probably the biggest issues we run into is non-disclosure. What can be disclosed and what can't be disclosed. The research community or academic community would always like to be published, where in our case depending on the project, we may or may not want that published."

From the community respondents' perspectives, non-disclosure amounts to the suppression of unfavorable research findings. Stated one (C5), "it becomes an unwritten rule that there are certain conclusions to which you might come that will not be acceptable, and therefore should not be let out. … it's not that the scientists involved are doing bad science, but if the results and conclusions of those studies are not propitious for the industry, those studies are simply deep-sixed." Some community respondents alluded that funding-related bias went beyond the non-publication of results to include the manipulation of research findings, a position not heard in the other three focus groups.

The relationship between funding source and credibility perceptions is important, because as all four groups noted, there are increasing pressures for scientist-industry and/or -government partnerships, and grants requiring industrial or other partnerships are more common. One scientist (S6) explained, "When you have an industrial collaborator there are more funding programs that you can access. So, I wouldn't say that it's easier, but just by virtue of having more programs you can go to, you can have more success." Stated another (S1): "I was very daunted at first by the necessity of collaborating directly with industry in Canada. There's no option, really, in sciences… well maybe that's a little hyperbolic. But it's really challenging to get funding [...] when it's not in partnership, because you have all these matching funds, and all these sort of things." An industry respondent (I6) stated that

partnership requirements have resulted in academic scientists approaching industry, as opposed to just industry approaching academic scientists: “when NSERC [Natural Sciences and Engineering Research Canada] Engage Grants came out, I had a whole collection of folks from physical sciences approaching [Company] with a collection of research interests, to say what are you interested in, and can we partner on…”

From the community respondents’ perspective, there is a systemic problem in the granting system. Stated one (C5):

> that whole systematic setup, funding for all of these projects, have corporate strings attached to them, presupposed conclusions are mandated, there are gag orders and all sorts of other things that prohibit good science from happening. And that’s the issue that needs to be addressed and quite frankly that’s much more a political issue than it is a scientific issue. There really isn’t any problems with our scientists, the problem is again just letting them get their word out in an independent, uninhibited manner.

We classify research funding as a primary theme, as Schapira, Imbert, Oh, Byhoff, & Shea (2014) found funding to be a factor in medical patients’ credibility perceptions.

Research methods: Scientists described research methods as central to the credibility of research, and emphasized transparency. In the words of one scientist (S7), credible information is “information obtained by a professional, using conventional methods used by this professional community or in wider terms, within the scientific paradigm. [...] The methods, how this information was obtained, should be detailed enough for them to be able to assess it.” Echoed another (S3), “making

sure experiments are measured and reproducible, well part of that is clearly explaining how you did these things. Because if someone else can objectively evaluate what you've done, then that's important for […] moving forward and using your results as scientific evidence in the future."

Industry and government respondents also discussed the importance of research methods to credibility, albeit in general terms. Industry respondents spoke of using established research methods to secure credibility: "[scientific information] should be reproducible if possible, and it should follow a rigorous method that everybody sort of agrees on, so it's part of the scientific method" (I7). Government respondents presented a similar position: "Credible scientific information is information that is arrived at after going through rigorous scientific methodologies, [and has a] value free conclusion" (G3). Another government respondent (G5) stated that research should be "built on existing literature" using "credible methods, reproducibility, and peer review."

When community respondents raised the issue of research methods with respect to credibility, they were concerned about incomplete or absent evidence. Stated one (C3): "There are places where studies have been done around nuclear power stations, but the sample sizes have been so small that it's been impossible to come to any firm conclusion. And those studies get used by the nuclear industry, who say it's perfectly safe." Others spoke about the need for pre-/post- studies, arguing that baseline health and environmental studies "were never done, although they were asked for; there is no baseline … so even if somebody wants to do the research, they have nothing to compare it to" (C2). The result, according to

community respondents, is that researchers cannot make credible claims about safety.

Previous research suggests that research methods are a key consideration to both scientists' and medical patients' credibility perceptions (Lach, List, Steel, & Shindler, 2003; Yamamoto, 2012; Schapira, Imbert, Oh, Byhoff, & Shea, 2014), making this a primary theme.

Publication: All groups explained that publishing research findings is critical to credibility. Scientists focused on peer review journals, and distinguished between different journals' quality, preferring "a journal that has a reputation for rigorous review" (S1).

Industry respondents also raised peer review: "As a company, working in a scientific department, what we look for [is] peer reviewed journal publications, and these things that give it credibility" (I6). They argued that publication in general, be it peer reviewed or not, is critical to allow for research transparency:

> It should be published so that other people can scrutinize it and see or establish if there's anything wrong with it… I think one of the key things for me is that the people who publish it understand the limitations and scope of that body of work, that [it] doesn't just apply to everything out there in the world and they know where to draw the boundary to that body of work. (I7)

Community respondents spoke of the importance of peer review and highlighted the challenges of distinguishing between legitimate and illegitimate journals: "there's a problem that has developed in the past few years with the arrival of a whole lot of new journals that basically people pay to get published. And the

peer review system is sort of not reliable in many of those, so I think we have to be a lot more cautious in what we accept and which journals we think as being legitimate" (C1).

As Young's research (2014) suggests peer review is an important factor to policy officials' credibility perceptions, we classify this as a primary theme.

Replication: Respondents across different groups raised the issue of established findings over numerous studies. In the words of one community respondent (C4), "it needs to be repeated thousands of times and not just one particular group, but by other groups as well."

Industry respondents, like the community respondents, also sought established evidence over time: "Is it verified data? Is it modeled? Is it a prediction, or is it something that you've been tracking over time and have a certain level of certainty about?" (I2). One respondent (I7) stated, "the body of evidence is continuously getting bigger, so before we will consider promoting it or not even quoting it but incorporating into our communications, it really has to be solid enough for us to lean on." Overall, from the industry respondents' perspective, it is important that information has a "track record" (I2); credible information "has to be more well-established" (I7).

Government respondents also raised issues of consensus and replication. The fact that scientific information may vary was seen as a natural part of the scientific world: "I can usually find an alternative scientific paper that disagrees. There is always two sides. Two independent researchers can come up with completely different conclusions" (G1). Here, they noted that credibility is established over time: "Academia can advance a debate in a more effective way than a company with a

specific interest, and they can do so in a way that allows clear thought and opinions to evolve. […] Climate change is a great example, it is 30 years among the scientific community. Scientists can help that debate if they do it carefully and credibly" (G4). Stated one respondent (G5), "The level of credibility might depend on novelty of scientific information being considered. Is the information being built on existing literature?"

As the theme of replication was not anticipated from the existing literature, (although Schapira, Imbert, Oh, Byhoff, & Shea's study (2014) of medical patients suggests the importance of the consistency of results), we classify it as emergent.

Summary: While the aspects of credibility were generally common across the stakeholder groups, there are variations in how the groups approached each. Previous literature conceptualizes credibility as consisting of perceptions of expertise and trustworthiness, and considering these two dimensions highlights the nuances among the stakeholder groups. Our results suggest that the groups differ in their assessments of what constitutes expertise, what demonstrates (or reduces) trustworthiness, and the relative prioritization of expertise versus trustworthiness.

Scientists expressed a keen focus on expertise, stressing the themes of knowledge source (scholarly training, body of work) and research methodologies as critical to assessing the credibility of a source. For scientists, discussions of trustworthiness emerged primarily around the theme of funding, with the argument that using established research techniques and transparency (i.e., openness about funding source, detailed disclosure of research method used, and replicability) are key to trustworthiness.

Industry and government respondents also stressed expertise (again through the themes of knowledge source (reputation) and research methodologies), but in more general terms than voiced by the scientists. Interestingly, in both the industry and government focus groups, an important distinction was made between their own assessments of credibility and the credibility assessments of the general public. Our data suggest that this distinction is warranted, as the community respondents emphasized issues of trustworthiness across all five themes. Community respondents particularly emphasized the theme of funding, and perceived industry funding as highly detrimental to trustworthiness. Differences between the community respondents and other respondents were also notable with respect to replication: while other groups felt that replicability (the potential to reproduce a study) demonstrated trustworthiness, community respondents argued that actual replication (reproduction of a study) is necessary.

Discussion and conclusion

This paper has explored the following research question: how do different actors vary in their understanding of what constitutes credible evidence? Credibility perceptions can influence the utilization of scientific evidence, both as a source for informing public debate and opinions and as a consideration in decision-making. Given this, it is useful to consider how different stakeholder groups assess research credibility.

Given the exploratory nature of this study, our sample size was limited to four focus groups and twenty-five participants. While this is acceptable for exploratory research, additional focus groups would be useful to fully explore categories and relationships within (and not only between) each of the stakeholder

groups, and to ensure saturation of ideas. This would be particularly valuable for the community group, given research demonstrating the diversity of public values that inform science attitudes (Gaskell et al., 2005; Priest, 2006; Kahan, Jenkins-Smith, & Braman, 2011). Our community participants had greater knowledge on the issue than uninvolved members of public; future research is needed on how additional segments of the public perceive credibility.

Further, as this exploratory study focuses on a specific risk issue (nuclear energy) with a limited qualitative sample, further research is required to assess whether the results apply to other risk issues, or other cultural or political contexts. Our purposive sample drew on overlapping interpretive communities with connections to nuclear policy in a specific political context. The topic's highly contentious and technical nature may have heightened credibility concerns, thus influencing the results.

While acknowledging these limitations, the study's findings suggest source credibility issues that may emerge with key audiences. One such consideration concerns science communication. Given their own prioritization of expertise as central to research credibility, scientists may be inclined to stress their research training and methodologies when communicating research, and may pay insufficient attention to demonstrating trustworthiness to non-science audiences. While the scientists we consulted felt that research transparency demonstrated trustworthiness, the fact that many non-scientists lack capacity to assess methodological choices means that such steps, while necessary, are likely insufficient. Horton, Peterson, Banerjee, & Peterson (2015) suggest that scientists

emphasize different aspects of credibility depending upon the particular situation and audience; our own research supports this idea.

It is also important to note nuances in groups' perceptions of expertise. With respect to the knowledge source, while scientists focus on the subject-specific credentials of the source, industry participants relied more on reputation, and government and community participants spoke solely of the sector within which the source works. These results suggest that, in practice, groups may differ greatly with respect to which individuals are legitimate experts. While scientists may not view an academic researcher with non-subject-specific training as a credible source, for example, other audiences may be satisfied with university affiliation or degree as a signal of credibility. Indeed, the industry participants raised this issue, arguing that medical doctors lacking training specific to the subject matter are often seen by the public as credible sources. Collins & Evans (2007) argue that there is a range of specialist expertises; while the scientists in our focus groups deemed only knowledge sources at the top of this range to be credible, the other stakeholder groups appeared to accept specialist expertises lower on this range as credible.

The varying perceptions of peer review are also of interest. While the scientists distinguished between the rigor of peer review processes, the other groups spoke of peer review in more generalized terms. For the community participants, there was some confusion regarding what constitutes legitimate peer review, an understandable question given the growing issue of predatory journals (Bartholomew, 2014). Thomm & Bromme (2012) argue that the accessibility of information on the Internet makes evaluating science credibility increasingly challenging, and find that laypeople often assess credibility in terms of how

"scientific" the information appears in terms of textual features; the presence of predatory journals complicates such assessments, and may contribute to the frustration voiced by the focus group participants. These findings suggest that third party entities that promote knowledge transfer may be particularly valuable in promoting informed public debate.

Important group differences with respect to perceived trustworthiness, and specifically the varying perceptions of funding sources, are of particular interest. University-industry collaborations are an important source of research funding, and are often encouraged through granting programs. However, the potential cost is reduced credibility in the eyes of some. Overall, these results raise questions about the potential impact of such models upon the broader perceived credibility of, and therefore trust placed in, university scientists.

Bauer, Allum, & Miller (2007) assert that "as long as science and society are not identical, the public's understanding of science as well as *scientists' understanding of the public* will continue to be a pressing issue" (p. 87, emphasis added). This exploratory study contributes to our understanding of non-science 'publics' (industry, government, community) through the finding that four primary themes (knowledge source, research methods, funding, peer review), each previously associated with one or two groups, are common across the four groups, and by identifying an emergent theme (replication). Our research suggests that, for some audiences, assessments of trustworthiness are central to credibility perceptions, reflecting the science and society paradigm. This line of research has the potential to improve scientists' understanding of non-science audiences.

While our purposive sample eliminates our ability to generalize our results to a representative population, this exploratory research study suggests a framework for future research examining credibility perceptions. Building on the science and society literature, as well as research in the management field that explores the importance of respect (Grover, 2013; Rogers & Ashforth, 2014), future research should consider how scientists can respectfully engage with audiences that prioritize trustworthiness and that have differing assessments of expertise when evaluating source credibility. In addition, future research should consider the relationship between credibility and non-technical sources of knowledge or expertise such as personal and familiar experiences held by communities – labelled cultural rationality (as opposed to technical rationality) (Fischer, 1995).

Future research should also examine how industry partnerships and funding relationships influence credibility perceptions and trust in science among the general public. A final area for future research is to consider how the engagement of scientists in contentious policy debates influences stakeholder groups' credibility perceptions. There are some who argue scientists should actively seek a stronger role in communicating research to public and policy audiences, due to their perceived credibility and independence. At the same time, the downsides of such efforts must be acknowledged.

Taken together, the results suggest that scientists who wish to promote the communication of their research beyond the academy should consider the specific credibility perspectives of their target audience, and understand the importance of demonstrating both expertise and trustworthiness. Across all groups, there was a general sense that credibility is a continuum; this feeling was captured by one

community respondent (C1), who stated, “I think there are kind of degrees of credibility, so that if some of those factors were missing, you might sort of accept it with some degree of credibility.” If research is to be utilized in public debate and decision-making, it is important to take steps to ensure the perceived ‘degree of credibility’ is high.

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