How knowledge contributors are legitimizing their posts on controversial scientific topics: A case of the measles, mumps, and rubella (MMR) vaccine

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Abstract

Traditionally, journalists, government agencies, and medical professionals have acted as mediators, facilitating the transfer of scientific knowledge from scientists to the general public. More recently, however, ordinary citizens are circumventing top-down mediation and contributing directly to discussions about scientific topics online. For the present study, we examined how these emerging mediators of online scientific information are shaping the discussion of hotly debated (at least within the public sphere) scientific topics, specifically, the alleged link between autism and the measles, mumps, and rubella (MMR) vaccine. Using content analysis, we have identified the resources that lay pro- and anti-vaccination knowledge contributors most often cite when making knowledge claims. Additionally, we examined how these contributors 1) use citations to legitimize their arguments; and, 2) take on particular roles in such arguments. Our results shed light on an emerging form of online science communication and the process by which knowledge contributed by ordinary citizens is shaping these online discussions. These findings have implications for online health information and health decision-making.

Contents

[Introduction](#)

[Lay knowledge contribution to science](#)

[Health and the MMR vaccine information online](#)

[Credibility of sources](#)

[Methods](#)

[Findings](#)

[Discussion and conclusions](#)

Introduction

Traditionally, scientific knowledge has been communicated to the public via mediators like journalists, who summarize (and sometimes synthesize) reports and white papers published by scientists into something more palpable to the general public (Brüggemann and Engesser, 2014). In these scenarios, the general public does not participate in knowledge co-production. They are simply the intended audience. Callon (1999) called this the “Public Education Model.” More recently, a new type of mediator has entered the knowledge production arena: namely, members of the general public — who may or may not have any sort of scientific background or training. These individuals can now take on the role of science mediator by writing and/or editing articles about scientific topics found on social media platforms like Wikipedia. In addition to Wikipedia, social media sites like Facebook and Yelp, have made it easier for laypeople to participate in the framing and/or co-production of knowledge — whether it be sharing travel tips (*e.g.*, Allen, 2010) or discussing possible causes of autism (*e.g.*, Kane, *et al.*, 2014).

This “co-production” framework (Jasanoff, 2004) can be applied to multiple contexts. As Wehrens (2014) asserts, this framework shows that science and societies are interwoven and that the flow of science knowledge is no longer unidirectional, *i.e.*, moving solely from scientists to society. In this paper, co-production of knowledge refers to laypeople engaging in knowledge production alongside scientists and experts (Callon, 1999). Historically, science and technology studies (STS) scholars have scrutinized scientist-dominated knowledge production. And while the idea of knowledge co-production has been around for approximately 20 years, this investigation is still a timely topic as the participation of lay co-contributors in this process — what Grand, *et al.* (2012) call “open science” — has grown significantly. In short, the boundary between knowledge producers and knowledge users has become blurred in recent years (Rycroft-Malone, *et al.*, 2016). Due to the ubiquitous nature of social medial platforms in modern life, it is easier than ever for laypeople to participate in knowledge co-production online.

One consequence of the rise of lay contribution to the production of knowledge is that the knowledge co-produced in most online environments is not typically vetted through traditional scientific processes, such as peer review. At a time when scientific knowledge has become politicized, evaluation of the quality of “scientific information” created, modified, and/or disseminated by lay audiences should be a key area of research in information science. Such an understanding is key to establishing best practices for scientists wishing to be more actively involved in this process and for educators seeking to how to best teach the public how to critically evaluate scientific information accessed on the Web. It becomes especially important on platforms where anyone can contribute content online, like Wikipedia (Stvilia, *et al.*, 2009) and some online health information sites (Zhang, *et al.*, 2015; Yi, *et al.*, 2012). The outcomes of this phenomenon can have positive or negative consequences (Rycroft-Malone, *et al.*, 2016). The positive consequence is the democratization of knowledge, while the negative is a growing potential for scientific opinion to be passed on as scientific fact.

The evaluation of information by lay audiences becomes especially important when considering scientific knowledge that is ostensibly controversial — for example, the human role in climate change, AIDS dissent in South Africa, and intelligent design, which, according to Ceccarelli (2011), were manufactured controversies despite a near universal consensus on such topics among scientists. Contentious topics like these are increasingly debated on social media platforms by both experts and laypeople (Liang, *et*

al., 2014; Prior, 2003; Setälä and VäLiterronen, 2014). We call these suppliers of information “knowledge contributors”. For example, Wynne (1996; 1992) argues that scientific knowledge production does not solely rely on scientists but also includes lay contribution. Wehrens (2014) expanded on this and identified the means which knowledge production is influenced by social practices. When discussing scientific topics that are controversial, identifying the reliability of the sources used to support particular positions are crucial (Jamieson and Hardy, 2014). Thus, there is a critical need to examine how ordinary citizens are interpreting and assessing the veracity of scientific knowledge.

In this paper, we examine the process in which knowledge contributors operate by asking the following questions: How are knowledge contributors legitimizing their posts on a controversial scientific topic? And more specifically, what type of sources are contributors using and what type of roles are contributors playing? Returning to the specific context of scientific information related to the alleged role of vaccines in the development of autism, we posit the following research questions:

RQ 1: When citing sources, what kind of sources do both anti- and pro-vaccination knowledge contributors use to establish their credibility?

RQ 1.1: How do these knowledge contributors use specific sources to legitimize their argument?

RQ 2: What specific roles do anti- and pro-vaccine knowledge contributors play to establish the legitimacy of their posts and positions?

The effective communication of scientific knowledge has become murkier and more complex partially because science communication now has new kinds of contributors who play a variety of roles (Bucchi, 2016). We investigate this growing phenomenon of lay knowledge contribution in tandem with these research questions to reveal the behaviors related to source citation as well as the evolving roles played by scientists, traditional mediators, and lay contributors within the context of online discussions surrounding the MMR vaccine.

Lay knowledge contribution to science

Many STS scholars have examined lay knowledge contribution to science (Boaz, *et al.*, 2016; Callon, 1999; Callon and Rabeharisoa, 2003; Kerr, *et al.*, 2007; Wynne, 1996, 1992). In terms of the interaction between scientists and laypeople with regard to knowledge production, there are three general perspectives to the research. The first assumes that scientists and laypeople who possess localized knowledge do not collaborate; instead they are fairly unreceptive to one another (*e.g.*, Wynne, 1996, 1992). The second sees explicit collaboration between scientists and laypeople (*e.g.*, Boaz, *et al.*, 2016; Callon and Rabeharisoa, 2003), which Callon (1999) called the “Co-production of Knowledge Model” [1]. A third type of research offers a slightly different take on this

second model, and identifies *naturally occurring* knowledge co-production between scientists and laypeople.

Wynne (1992) examination of the sheep farming community of Cumbria, an area of Northern England, in the aftermath of the Chernobyl accident serves as one example of this first perspective of research. Wynne's research found that, when investigating the accident's effect, the farmers of the region and scientists there for the study failed to communicate with each other effectively. His research indicated that through interactions between farmers and scientists each group attempted to defend their social identity. The farmers reported that they felt their expertise was being ignored by the scientists' denials. The scientists in turn defended their standardized methodology which they claimed was at the center of their identity. This study found that laypeople were more thoughtful about the limitations of their knowledge (*e.g.*, the farmers acknowledged the need for scientific expertise) than experts. In addition, the scientists, using standardized methods, sometimes overcautious about the accident, whereas the farmers, who had local and situated knowledge, more than not spotted connections the scientists had missed. Thus, Wynne discovered a complex relationship between social identity, credibility, and trust of institutional knowledge.

As a seminal work in the second branch of research, while studying the efforts of the French Muscular Dystrophy Association (*Association Française contre les Myopathies* or *AFM*), Callon and Rabeharisoa (2003) found expert knowledge and lay knowledge to be complementary, and, in fact, not intrinsically different. The lay "research in the wild" — which goes beyond traditional patient participation — pairs well with traditional laboratory research. This type of collaboration brings both the direct concern and experience of laypeople and the expertise and resources of scientific laboratories to address research problems. Kerr, *et al.* (2007) also discussed the important contribution of the "expert patient" who provides contextual health knowledge, especially in regard to treatment, to health scientists in recent years. At the same time, when examining a forum in which experts and lay people were engaged in discussions about genetics, they found that experts with technical knowledge tend to be more valued. In another study, Boaz, *et al.* (2016) interviewed researchers from the U.K.'s Biomedical Research Centres. They found that understanding and openness to patient and public involvement in research varied among researchers and that the traditional approach to the knowledge deficit model persisted.

In recent years, the third perspective on collaboration between scientists and laypeople appears more in health-related topics. "Apomediation" (Eysenbach, 2008) is a term used to describe the process in which users receive healthcare guidance from networked collaborative filtering (*e.g.*, "wisdom of the crowd") rather than professionals or members of their social network. Apomediation has become more prevalent with the widespread use of social media platforms, such as PatientsLikeMe (Kazmer, *et al.*, 2014). In general, previous research showed that although lay contribution is valuable and important, laypeople may have a limited understanding of fundamental scientific knowledge. Thus, it is necessary to discuss the widespread availability and consumption of health information online, especially in the context of our research questions.

Health and the MMR vaccine information online

The increased volume of health information now available online has prompted researchers to turn their attention to popular online sources (like Wikipedia) as well as relevant health Web sites (*e.g.*, Zhang, *et al.*, 2015). And while these Web sites have the potential to be informative for laypeople, online media is also rife with rumors, half-truths, and misinformation on a number of scientific topics, including health-related topics. Vraga and Bode (2017) demonstrate the importance of correcting online misinformation in an experimental study that examined attempts to correct misinformation about the Zika virus circulating at the time of the study. Using Twitter feeds specifically constructed for the study, they found that corrections disseminated by authoritative organizations, such as the Centers for Disease Control and Prevention (CDC), were especially effective in helping participants reject inaccurate information about the Zika virus.

In the case of the MMR vaccine, mediators who interpret and translate original scientific findings between scientists and laypeople have traditionally tended to be journalists (*e.g.*, Allgaier, *et al.*, 2013; Liang, *et al.*, 2014; Mikulak, 2011) and healthcare professionals (*e.g.*, Shelby and Ernst, 2013). These traditional types of mediators have been well studied. For example, Mikulak (2011) explored scientists' attempts to communicate their findings reliably, looking closely at both journalistic claims of "neutral" and balanced reporting and shifting public attitudes toward acceptance or rejection of scientific knowledge. Specifically, she examined the controversy surrounding the MMR vaccine and concluded that scientists have more power to frame the scientific debate accurately and inform the public than do journalists and other members of the public.

However, research on parents' information-seeking and decision-making behaviors regarding the MMR vaccination is less conclusive. For example, Shourie, *et al.* (2013) tested whether information aids would help encourage parents to vaccinate their children. Their findings indicate that the difficulties faced by parents when making such decisions decreased with online and pamphlet information intervention, although the impact on the decision to vaccinate was unclear.

More recently, new studies have examined how social media influences parents' MMR vaccination decision-making. Aquino, *et al.* (2017) analyzed the use of Google searches, tweets, and Facebook posts about the MMR vaccination in Italy and found that searches on the alleged dangers of the MMR vaccine increased after an Italian court decision regarding vaccine injury compensation in 2012. The authors examined vaccination rates in Italy following the court's decision and found that they had begun to decline, despite a reversal in 2015 of the court's earlier judgement.

Additionally, Krishna (2017) studied those who lack proper knowledge but are vocally against vaccines, or "lacuna individuals". In the study, quasi-lacuna individuals (those who have two of the three characteristics of lacuna individuals) tended to overstate the risks of vaccines, to conceptualize vaccines as social — rather than medical — issues, and were more actively involved in discussing and sharing their own opinions about vaccines. Quasi-lacuna individuals also tended to be less trusting of information provided by the government, pharmaceutical companies, and healthcare professionals and were more likely to have engaged in the active dissemination of misinformation via social media. This type of lay knowledge sharing has expedited the spread of MMR vaccine

skepticism, leading to decreasing vaccine rates in some countries. In the United States, the MMR vaccine rate has reached a historic low in certain geographic areas (Keneally and Orsini, 2019). Olive, *et al.* (2018) believes this may be due to widespread misinformation regarding the MMR vaccine spread by the anti-vaccine movement. In sum, social media platforms enable lay individuals to share and advocate for misinformation partially because these platforms provide opportunities for laypeople to become un-checked knowledge contributors on contentious topics, such as the MMR vaccine (Magra, 2019).

The current paper investigates the process by which a position opposed to the MMR vaccine is legitimized by focusing on the sources that participants use to educate themselves and the roles that participants play in framing and disseminating information related to the topic. One of the major themes we found was a focus on the credibility of specific sources. This focus is a major influence on the ways in which individuals contribute knowledge about controversial topics, and how much credence is given to particular sources. As such, determining how lay information seekers assess the credibility of specific resources, how they determine whether a source is credible (or easily discredited), and how such boundaries are drawn and defended.

Credibility of sources

For the present study, credibility has been assessed in relation to source, media, and message (Rieh and Danielson, 2007; Riesch and Mendel, 2014). When discussing scientific knowledge, the perceived credibility of the source is a natural focus (Gieryn, 1999). As such, we focused primarily on how sources are used and the process by which sources are legitimized as credible. Because knowledge contributors in certain online forums are unknown to readers, source credibility also has the potential to influence message credibility and vice versa. Previous research found that online contributors establish credibility in various ways. Lewandowsky, *et al.*'s (2012) comprehensive literature review on misinformation cautioned that information found online can be misleading, which is an important consideration given that many American adults gravitate to online resources when seeking health information. This reliance on online media sources may reinforce some information seekers' own perspectives, where "liking" or "upvoting" news and information that confirms one's own biases results in the creation of an online "echo chamber" (Goldie, *et al.*, 2014; Colleoni, *et al.*, 2014).

In a study about conceptualizing "trust" within the context of the evaluation of health information, Johnson, *et al.* (2015) identified seven constructs that assist information seekers in the assessment of information trustworthiness: reliable content; credibility assessment; personal recommendation; ease of use; usefulness assessment; readability; and, brand (*i.e.*, logo). The authors concluded that the most important factor influencing users' perspectives on credibility and usefulness was the content itself; however, appearance and ease of use were also major factors. But sometimes, it is the messenger who lends trustworthiness to information. For example, Brulle, *et al.* (2012) measured public opinion using a poll on climate change and found that politicians and advocacy groups influence public perception of the seriousness of climate change than scientific

articles or news media to some extent. In the same vein, Jamieson and Hardy (2014) conducted an experiment in which sources of evidence were manipulated to raise the issue of climate change among the general public. Their use of evidence included a politician's speech, an interview with a scientist, and a graphic visual of average monthly Arctic sea ice changes. They found that the graphic image was a powerful way to convey the threat of climate change, regardless of participants' political views.

Finally, additional sources also influence credibility by allowing triangulation of the information. Lederman, *et al.* (2014) studied evaluation criteria for the credibility of information in online health forums and found that participants gave more credence to information that had been verified by outside sources, the perceived credibility of those sources, quality of the argument made, contributor literacy, and crowd consensus. In sum, the research suggests that multiple factors affect the perception of the credibility of messages posted online.

Methods

After the study was approved by the Institutional Review Board, data were collected from complete, publicly available online threads involving discussions of the MMR vaccine and the vaccine-autism controversy, on two popular Web sites: BabyCenter.com (<https://www.babycenter.com>) and Wikipedia (<https://www.wikipedia.org>). Data reviewed included 541 posts referencing MMR and/or the MMR controversy from 33 threads between 2007 and 2013 on Baby Center and data from Wikipedia harvested from both the MMR and MMR Vaccine Controversy talk pages, which included 705 posts from 119 threads between 2004 and 2013. A total of 1,246 posts were analyzed. The data were a subset of a larger data set from the previous study (Hara and Sanfilippo, 2016). For the current study, we extracted the posts that were coded as “citations,” which was defined as “any discussions of or citing of sources to justify facts or background knowledge for the purpose of convincing others” [2].

We systematically approached the textual analysis of these posts using a previously developed and tested codebook (Hara and Sanfilippo, 2017). The first step of the coding process identified cited sources (Round 1). Round 2 involved linking the individuals who cited certain sources to a stance: anti- or pro-vaccination. Round 3 connected sources and stances to the role that individuals played in the construction of knowledge about the MMR vaccine online. In Round 4, the final stage, the accuracy of coding was checked and any coding errors were corrected.

The codebook, detailed in [Table 1](#), was developed based on the examination of pilot data by the authors. We then tested the codes with another set of data to verify that the categories were exhaustive and exclusive. The roles that participants played included helpers, distractors, and facilitators. Codes were applied as appropriate, with no limit to the total number that could be applied to a post. Some posts cited information from multiple types of sources and therefore required more than one code. Frequencies of codes were compared across communities and across positions in the controversy. The accumulated number of codes were supplemented by quotes from the posts. Qualitative

analysis of these quotes provided a more nuanced understanding of how participants understood and engaged with different types of citations and citation sources.

Furthermore, a thread was identified as controversial when a thread included at least two clearly conflicting perspectives. We analyzed code counts by controversy position between the two communities: first, by including all discussions and uses of citations, and then by narrowing the scope to include only direct uses of citations to support one's own position. Cross-tabulating these two types of codes allowed us to see which types of participants from which communities drew on certain sources more frequently. This highlighted the actors most likely to challenge the legitimacy of certain types of citations.

We then assigned additional coding to posts that included direct citations or posts that questioned the credibility of cited sources. This additional coding identified the type of source discussed by each poster. Participants' discussions about the necessity of providing citations were not included unless they referenced specific types of sources. We coded these posts based on the type of citation source used or debated, identifying whether participants cited or contested citations from academic sources, government organizations, non-governmental organizations, Web sites, blogs, news media, legal sources, or non-academic publication sources.

Academic sources included medical journal articles and academic texts; government and non-governmental organizations often included epidemiological statistics and public health guidelines. Web sites and blogs were often subject to interrogation due to suspect credibility and included personal blogging sites, politically-oriented Web pages, and Google search results. We used two separate coding approaches for Web sites and blogs because previous research indicated that personal blogs play a vital role in sharing scientific knowledge (Bubela, *et al.*, 2009; Jarreau and Porter, 2018; Kouper, 2010). Therefore, it is important to differentiate personal blogs from other general Web sites. Citations of news media ranged from newspaper articles to magazines and broadcast network news. Legal sources were primarily limited to publicly available documents of litigation proceedings. Non-academic publications included books on vaccination and health marketed toward laypeople. Finally, we coded citation-related posts as either representing pro-vaccination or anti-vaccination stances, following the practice reported by Fadda, *et al.* (2015) (see the codebook for positions in [Table 1](#)).

To obtain satisfactory inter-coder reliability, we went through multiple iterations of the codebook. One of the authors was the primary coder, and a research assistant was enlisted as the second coder. Inter-coder reliability was calculated with the citation sources and positions in Cohen's Kappa, and all of the values were between 0.43 and 1. According to Hallgren (2012), 0.41-0.60 in Cohen's Kappa value indicates moderate agreement for inter-coder reliability and 0.8-1 suggests perfect agreement (Hallgren, 2012). When there were differences in coding, the two coders discussed how they coded and then reached an agreement. Specifically, differences in coding were resolved through an agreement to code posts in light of the posters' previously expressed stance (anti-vaccination or pro-vaccination) rather than to code each post as a decontextualized entity. This mutual understanding allowed the coders to reach agreement.

Table 1: Codebooks..

Codebook for citations	
Code	Definition
Academic sources	Sources that are peer-reviewed academic journal articles and academic textbooks
Blog	Includes smaller personal blogs as well as more popular science blogs and the blogs of magazines and journals
Government sources	Government publications and Web sites, <i>e.g.</i> , Center for Disease Control and Prevention (CDC) Web site (https://www.cdc.gov)
Legal	Publicly available documents of litigation proceedings
News media	News sources including newspapers and media Web sites
Non-governmental organizations	Publications created by non-government organizations, <i>e.g.</i> , American Pediatric Association
Non-academic publication sources	Books and magazines on vaccination and health marketed toward laypeople
Web sites	Sites provided by non-government organizations, news media, and legal Web sites
Codebook for positions	
Code	Definition
Pro	Directly expresses views in favor of vaccinations; all posts for a single user are coded “Pro” if poster clearly expresses pro-

	vaccination opinions in their posts
Anti	Directly expresses views against vaccinations; all posts for a single user are coded “Anti”; if poster clearly expresses anti-vaccination opinions in any post
Codebook for roles (Adapted from Hara and Sanfilippo, 2017)	
Code	Definition
Distractor	Has a negative impact on the discussion process, either by distracting, interrupting, trolling, or through vandalism
Helper	Provides information, knowledge, and/or experience based on help sought by the original poster or any mover who reshaped the overall discussion
Seeker	Asks for help to make sense of the issue at hand
Mover	Serves as a highly specialized facilitator; transitions or funnels the discussion to new or adjacent points
Judge	Evaluates and/or requests justification for changes in content, process, and style; also evaluates statements and actions
Knowledge Shaper	Removes content or rewrites, without adding, in order to convey coherence, simplicity, or a particular perspective
Organizer	Summarizes discussions rather than shaping content; synthesizes and represents the information

	into a more usable set of links or facts
Reflective Reframing [Reframer]	Reconstructs consensus; translates information collectively deemed useful into informative and consistent content
Reflective reinforcing [Reinforcer]	Seeks to reinforce identified truths and reconstruct the consensus by repeating conclusions and providing evidence in support of the consensus
Cross-Thread Connectivity [Connector]	Coordinates multiple topics to provide consistency and continuity
Facilitator	Smooths and expedites quorums and moderates discussions for the purpose of progress
Governance-Oriented Approach [Governor]	An experienced user or someone with an interest in protecting established policies; enforces said policies
Mediator	Similar to facilitators, but specifically manages conflicts within discussions
Supporter	Provides support for positions articulated within discussions; seeks out references to support claims and positions
Unmasker	Investigates the behaviors of possible perpetrators in order to expose these perceived harmful actors

Findings

Our findings indicate that understanding both the sources used and roles played by online actors engaged in the debate surrounding MMR vaccine are crucial for our understanding of how knowledge is co-constructed on social media platforms. We show how differences in the sources cited reflect and elicit certain normative beliefs about science as trustworthy and what counts as credible. Different actors play different roles constructing scientific knowledge online and defining boundaries between credible and dubious sources. Online contributors who, in making evaluative claims about sources and arguments, shape the intersection between scientific and lay knowledges and their interpretations in determining what is true, credible, biased, or false. We analyze these patterns further in this section, presenting supporting quotes and quantitative data.

Content and controversy position for citation post

First, to investigate research questions 1 and 1.1, we analyzed the type of content posted, ranging from editorial, background knowledge, and media report to citation and vandalism (see reference removed for blind review) as well as the user's stance on MMR vaccination (*i.e.*, anti- or pro-vaccination). Then, we examined all posts coded as "citation," which indicated users who cited sources to justify their positions. [Table 2](#) summarizes our findings; we identified how contributors in different positions used various sources to persuade others.

Table 2: Citation type of position in percentages..				
	Baby Center		Wikipedia	
	Pro	Anti	Pro	Anti
Academic	40.5%	10.3%	30.9%	12.5%
Blogs	4.8%	2.6%	3.3%	0%
Government	7.1%	20.5%	3.9%	7.8%
Legal	0%	0%	8.3%	4.7%
News media	11.9%	10.3%	18.2%	17.2%
Non-governmental organizations	4.8%	7.7%	6.6%	6.3%
Non-academic publications	4.8%	15.4%	4.4%	3.1%
Web sites	26.2%	33.3%	24.3%	48.4%
<i>N</i>	42	39	181	64

Academic research citations

It is not surprising that an overwhelmingly higher number of pro-vaccination contributors cited academic research than anti-vaccination contributors, a finding that extended across both sites considered here. Contributors did not engage in many debates regarding the credibility of academic sources. There appeared to be an unspoken agreement that academic sources are trustworthy among all contributors. In fact, Wikipedia has a specific policy about encouraging the use of academic peer-reviewed sources (WP:MEDRS) [3]. Our data indicate that contributors generally seemed to have accepted the established credibility of academia. For example, Wikipedia hosted a debate on whether an editorial in a medical journal should be considered credible or just akin to news media information because the author was a journalist. This presupposes that regular, research-based academic articles are generally credible. The following exchange between two Wikipedia users illustrates the core of the debate:

I like the new additions, but this line bugs me: “According to WebMD, the BMJ [British Medical Journal] article also claimed...” Shouldn’t we just cite what the BMJ article says? (I recognize it’s harder to access, but it’s certainly a more reliable source than WebMD.) [WP-019]

No, because the BMJ article is written by Brian Deer, an investigative journalist, who was the driving force behind the investigation, so we need to also access what other reliable sources say about the BMJ report ... The BMJ article was not written by a doctor — it was written by a journalist. [WP-082]

This exchange presented a sophisticated understanding of the difference between various sources. The participants were questioning the credibility of an individual article written by a journalist, not a scientist whose article would be published in a credible scientific journal. In general, both of the pro-vaccination contributors in the above quote often used these kinds of academic sources to bolster their arguments.

Web site citations

Non-academic Web sites were often cited to support arguments made primarily by anti-vaccination contributors on both sites. In total, 33.3 percent and 48.4 percent of the citations made by anti-vaccination contributors on Baby Center and Wikipedia respectively pointed to non-academic Web sites. However, pro-vaccination contributors also cited non-academic sites (26.2 percent in Baby Center and 24.3 percent in Wikipedia). Our data is consistent with literature findings that indicate non-academic Web sites support a broad range of beliefs and perspectives due to the interactive nature of Web 2.0 (Adams, 2010) and social media (Chou, *et al.*, 2018), compared to scholarly articles, which strongly support pro-vaccination messages (Dudley, *et al.* 2018). For instance, a Wikipedia user criticized one Web site when writing:

I should have stopped reading as soon as I saw a link to Natural News presented as evidence ... as for the deaths from vaccines, it’s like pointing to the number of deaths caused by motorcycle helmets falling off a shelf and hitting someone in the head to argue that motorcyclists are therefore better off

not wearing a helmet. I don't think Wikipedia is necessarily the best place to educate people with a complete lack of understanding of science and medicine. [WP-019]

The discussions above primarily involved pro-vaccination contributors questioning a variety of Web sites cited by anti-vaccination contributors. In fact, the credibility of certain sites is one of the main debates on Baby Center and Wikipedia. Among all the sources cited, Web site citations were the most controversial and sparked the most debate about credibility.

News media citations

Citations of news media sources are more evenly split between sides, though these were the sources slightly more frequently referenced by pro-vaccination contributors. This was consistent on both Baby Center and Wikipedia. Wikipedia contributors on both sides of the issue used news media, although these numbers were more skewed toward pro-vaccination contributors. Those who support vaccination typically used these sources to reinforce the same or similar information from other types of sources, including research findings published in academic journals and information presented on both government and independent Web sites. Contributors also engaged in debate over what type of news sources should be considered credible. One Wikipedia user commented, "It is science that determines whether MMR vaccinations are dangerous, not Judges, not juries, not CBS News" [WP-053]. When the anti-vaccination contributors use news media as sources, they tend to cite news articles that discuss some problems with vaccines, but not necessarily the articles that cover the link between the MMR vaccine and autism. In addition, anti-vaccination contributors sometimes focus on the fact that the MMR controversy does not have 100 percent consensus among scientists. For example, one of the contributors posted citing an article about a scientist who does not univocally deny the link between the MMR vaccine and autism:

It was NEVER scientifically proven that vaccines do NOT cause autism. Show me a SINGLE study that shows this. You can't, because it doesn't exist. However, new studies like this one http://www.cbsnews.com/8301-31727_162-20049118-10391695.html?tag=latest show that there are possible connections between vaccines and autism ... [BP-085]

Government information citations

Surprisingly, Baby Center contributors on the anti-vaccination side referred to government sources (e.g., U.S. Department of Education, U.S. Department of Health and Human Services, U.S. Food and Drug Administration, and British National Health Service) more than pro-vaccination contributors. This seemed to be a strategy to bolster the credibility of their arguments, given that the statistics provided by different agencies and organizations are more open to interpretation than are the more explicitly-stated findings in academic research publications. For example, one anti-vaccination contributor on Baby Center wrote:

FYI a fully vaccinated child can catch and spread the same diseases that an unvaccinated child can because there are no vaccines that are 100% effective. Check out some recent outbreaks and around 70% have been vaccinated. Mortality rates were on the decline from all of these diseases for years before vaccinations were introduced. It is a very personal decision. I suggest you research the actual diseases and how many died from these diseases pre-vaccination versus post-vaccination. (it's on the CDC website). [BC-011]

Anti-vaccination contributors tend to focus on potential adverse effects and occurrences of adverse effects as evidence to argue against vaccination.

Legal source citations and the rarity of blog citations

Legal sources were almost entirely limited to the discussion of one court case on Wikipedia. Anti-vaccination contributors introduced it as a source, with pro-vaccination contributors debating the validity of court documents as good sources for medical information. Furthermore, blogs were very rarely cited, and when these citations did appear, they were scattered across both sides of the issue. On Wikipedia, the main discussion about blogs concerned the credibility of blogs used as citation sources, and contributors infrequently used blogs in support of their arguments about the vaccination. This observation was somewhat surprising because science blogs have been reported to be a popular method of science communication (Riesch and Mendel, 2014). At the same time, we assumed that blogs may not have been established as credible sources in the eyes of Wikipedians due to the fact that blog contributors vary from scientists and journalists to amateurs.

Non-governmental organizations and Non-academic publications

Both pro- and anti-vaccination contributors in Wikipedia cited non-governmental organizations (6.6 percent and 6.3 percent for pro- and anti-vaccination contributors respectively) and non-academic publications (4.4 percent and 3.1 percent (pro- and anti- respectively) in similar percentages. On the contrary, anti-vaccination contributors (7.7 percent and 15.4 percent for non-governmental organizations and non-academic publications respectively) on Baby Center cited more of these sources than pro-vaccination contributors (4.8 percent and 4.8 percent for non-governmental organizations and non-academic publications respectively). As mentioned earlier, Wikipedia has specific policies regarding the type of appropriate citations whereas Baby Center does not. This probably affected the way that contributors used their sources to legitimize their argument. For example, one Wikipedia contributor wrote:

The popular press is generally not a reliable source for scientific and medical information in articles. Most medical news articles fail to discuss important issues such as evidence quality,[11] costs, and risks versus benefits,[12] and news articles too often convey wrong or misleading information about health care.[13] Articles in newspapers and popular magazines generally lack the context to judge experimental results. WP:MEDRS [WP-59]

This quote reveals how Wikipedia policies establish what is and what is not a “reliable source of information”. As a result, the ways in which contributors on Wikipedia contribute to knowledge production is shaped in part by rules and shared norms. In Wikipedia, both anti- and pro-vaccination contributors used fewer non-governmental organizations and non-academic publications than most other sources. Since there was no policy to evaluate citations on Baby Center, users were less constrained in terms of which type of sources could be cited to support one’s position. As such, sources that may be considered overly biased on Wikipedia were used more frequently on Baby Center.

Roles and controversy position for all posts

We now address research question 2, which concerns how contributors use certain roles on either side of the MMR vaccine controversy to legitimize their posts. We compared contributors’ particular roles (*e.g.*, information seeker, helper, organizer, distractor, facilitator) with the posters’ positions (*i.e.*, pro- and anti-vaccination). [Table 3](#) summarizes our findings.

Table 3: Roles and controversy position for all posts in percentages..				
	Baby Center		Wikipedia	
	Pro	Anti	Pro	Anti
Distractor	12.0%	34.4%	12.0%	34.8%
Reframer	5.5%	3.2%	5.9%	2.4%
Seeker	2.8%	4.9%	3.7%	6.4%
Supporter	6.4%	11.0%	10.8%	6.4%
Helper	46.0%	38.0%	11.8%	12.0%
Judge	13.2%	6.5%	23.7%	18.4%
Governor	0%	0%	6.2%	2.0%
Knowledge shaper	0.6%	0%	5.4%	3.2%
Facilitator	1.2%	0%	1.1%	0.4%
Mediator	4.0%	1.0%	2.5%	2.4%
Organizer	0%	0%	1.7%	1.2%
Reinforcer	3.7%	1.0%	4.1%	3.2%
Unmasker	1.8%	0%	0.3%	0%
Connector	1.5%	0%	4.7%	1.6%
Mover	1.2%	0%	6.3%	5.6%
<i>N</i>	326	308	761	250

Judge and governor roles on Wikipedia

On Wikipedia, the pro-vaccination contributors who had been assigned the role of judge numbered highest percentage (23.7 percent) among all roles. One user wrote:

Of course there must be research to once and for all settle the issue of vaccine-induced autism. I have stated numerous times that a more serious source than w hale -dot- to [4] can count on my support. But w hale -dot- to does not appear interested in calm, rational debate — its webmasters have chosen to attack the medical profession in its entirety, and probably would disagree with the research methodology of any study that disproves links between vaccines and illness ... But medical school has taught me to examine scientific evidence. [WP-27]

This pro-vaccination contributor explicitly criticized the objectivity and validity of the Web site source in question, while also making an explicit claim for his or her professional role as a physician. The Web site implicated was passionately debated because of its strong anti-vaccination and anti-allopathic medicine stance, stances which pro-vaccination contributors considered more akin to “conspiracy theories”. Furthermore, asserting one’s position as a doctor on a medical controversy discussion forum is likely an attempt on the part of the poster to ascribe greater authority to his/her argument. Another pro-vaccination user acted as a judge when commenting, “*Per WP:MEDRSv, a publication in a peer-reviewed publication, such as the British Medical Journal, trumps your opinion WP-71, by a lot*” [WP-35]. This quote reveals the emphasis placed on scientific research and peer-reviewed publications as representative of scientific truth, and implies that those who disagree have no comparable evidence beyond personal convictions.

Additionally, on Wikipedia, many of the contributors who acted in judge roles simultaneously held governor roles. For example, one pro-vaccination contributor suggested that the word “controversy” should be reconsidered in the article title:

If parents look up this article, it should be clear that Wakefield’s allegation of a link between the MMR vaccine and autism is fraudulent [sic]. Baird G, Pickles A, Simonoff E et al. (2008). ‘Measles vaccination and antibody response in autism spectrum disorders’. Arch Dis Child. doi:10.1136/adc.2007.122937. PMID 18252754. Lay summary — The Guardian (2008-02-05). [WP-90]

This contributor acted as a governor, that is, someone who pays attention to other users’ compliance to Wikipedia policies, by motioning to edit the title and tone of the article, and made an authoritative statement supported by an academic journal citation.

Pro-vaccination users held an undeniable position of power on Wikipedia, not only because they comprised the majority of posters but also because the expectation of high-quality sources (e.g., peer-reviewed academic journal articles), defined by its policies for claims, gave pro-vaccination users an upper hand. They appeared to understand that academic journals, physicians' declarations, and double-blind trials are more credible, especially in the context of a medical article partially written by medical professionals, than news sources, small Web sites, and blogs.

Most common roles on Baby Center — Helper, judge, distractor

On Baby Center, the helper and judge roles were the top two most frequently played by pro-vaccination users (46 percent and 13.2 percent respectively) whereas helpers and distractors most frequently appeared among anti-vaccination contributors (38 percent and 34.4 percent respectively). Some anti-vaccination users took on the role of distractor by trying to use “credible” sources to defend their position, though these sources often did not actually address the autism controversy. For example, one anti-vaccination Baby Center user posted, “*Similarly, Dr Michel Odent found that 5 times as many children who had had the whooping cough vaccine had asthma than children who had not had the vaccine*” [BC-30]. This reference to research by a certified medical doctor attempted to appeal to what was seen as credible knowledge but distracted from the discussion of autism at hand as well as the main concern of the ongoing thread.

When pro-vaccination contributors acted as distractors on Baby Center (12.0 percent), it was in the context of engaging in personal, heated arguments with those holding opposing views, a phenomenon which also holds true for the pro-vaccination distractors in the Wikipedia data. Similar to the anti-vaccination contributors on Baby Center, the main contributors to the argument on Wikipedia, primarily distractors (12.0 percent), often referred to other instances of the questionable safety and usefulness of vaccines or medical intervention. Distractors' comments were typically impassioned and, not surprisingly, more focused on winning arguments. For example, one anti-vaccination Baby Center contributor wrote:

It was NEVER proven that vaccines do NOT cause autism.
Show me a single study. You CAN'T because it doesn't exist.
However, there are studies that shows that there may be a
connection. The most recent study like this one
http://www.cbsnews.com/8301-31727_162-20049118-10391695.html?tag=latest show that there is a possible
connection between vaccines and autism. Please do some
research instead of listening to the CDC and vaccine
manufacturers before posting such ignorant statements [BC-02].

This contributor was coded “helper” and “distractor” because the comment was distractive yet provided some information about the vaccine, no matter the validity of the information. Interestingly, patterns between users' roles and controversy positions did not always align across all sources of data.

On Baby Center, pro-vaccination contributors were more likely to be helpers (46 percent), and this role was similarly dominant among anti-vaccination contributors (38

percent). This can be explained by the overall attitudes about the MMR vaccination expressed on each site. Baby Center had more outspoken anti-vaccination contributors/posters who often dominated certain threads and left pro-vaccination contributors concerned and outnumbered. In other words, Baby Center had more users who repeatedly commented and engaged with other users to support their anti-vaccination position.

Differences between Wikipedia and Baby Center contributors

On the Wikipedia talk pages, pro-vaccination contributors were clearly the dominant group (see Tables [2](#) and [3](#)) and, as discussed earlier, held more sway and influence over changes made to the page. As shown in Table 3, a greater percentage of pro-vaccination contributors in Wikipedia occupied judge and governor roles, roles which confer sway and influence. Therefore, contributors acting as helpers often entered discussions to support those with similar positions on the MMR/autism topic when those with opposing views began to dominate and attempt to silence the minority opinion. In response to this, anti-vaccination contributors on Wikipedia helped other anti-vaccination users, such as this individual:

Instead of povishly [sic] mocking the w hale -dot- to archive resource with the ‘fringe’ mantra, it would be more accurate, and less misleading, if the term ‘suppressed’ was substituted for describing the type of knowledge archived there. The webmaster apparently has good reason for his disillusionment with medical authorities out of touch with the immense scope of human suffering caused by vaccine injuries, as he describes how such a tragedy happened to his family at w hale -dot- to. [WP-03]

This contributor implored other Wikipedia contributors to take anti-vaccination views seriously and indirectly implied that there was legitimate harm caused by vaccines by alluding to the other user’s personal experiences.

Another anti-vaccination user posted:

These FACTS are important for anyone researching the MMR Autsim link. Documents emerge proving Dr Andrew Wakefield innocent; BMJ and Brian Deer caught misrepresenting the facts[.] Learn more: [link provided]. [WP-20]

Of note are the deliberate capitalization of the word “facts” and the inclusion of a link to an article providing information about the supposed harms of vaccine. The link directed to a “natural news” Web site containing an array of anti-vaccination information and many endorsements of homeopathic and alternative health approaches. It is also important to mention that this link, because of its “biased” and “non-scientific” source, was quickly ignored and excluded from the article. However, this post still demonstrates how anti-vaccination contributors on Wikipedia attempted to add sources and

explanations of their views to support the arguments made by similarly minded contributors.

Additional roles and connected positions on both sites

Other roles occurred less frequently but still exhibited notable patterns. For instance, the mediator role was primarily occupied by pro-vaccination users on Baby Center (four percent for pro- vs. one percent for anti-vaccination). Comments like “*Don’t swallow the baseless fear pill. As everyone keeps saying, “do your research” — go to PubMed (<http://www.ncbi.nlm.nih.gov/pubmed/>) and look at some real data instead of a website made by the parasites whose only paycheck comes from fear,*” [BC-78] made by a Baby Center contributor, attempted to mediate controversial threads by encouraging other users to calm down, think rationally, and consult the medical research on the subject. On Wikipedia, a post consisting of “*Now back to the actual discussion. This all started because Wikipedia has a policy (WP:NPOVvi) that states explicitly that not every minority view needs mentioning*” [WP-27] exemplified how pro-vaccination contributors made an effort to mediate the discussion by steering it back on track, while at the same time directing larger sentiments toward their viewpoint.

In sum, we address two major research questions. First (*RQ 1* and *RQ 1.1*), we studied the types of sources that Wikipedia and Baby Center contributors used to support their arguments and positions regarding MMR vaccine, and how these sources are used to bolster such arguments. Both sites we examined had similar patterns regarding citation sources. In general, pro-vaccination contributors tended to use academic sources whereas anti-vaccination contributors tended to use Web sites when arguing their position. This is likely due to the dearth of academic research supporting anti-vaccination viewpoints, whereas pro-vaccination arguments are generally supported by existing medical and scientific journal publications. Therefore, anti-vaccination contributors need to find sources supporting their views elsewhere, such as on Web sites. Surprisingly, anti-vaccination contributors on Baby Center used government sources to endorse their argument more than any other type of source except for Web sites. We did not find a similar pattern for Wikipedia anti-vaccination contributors, most likely because Wikipedia has explicit citation validity guidelines.

Our second major research question (*RQ 2*) considered the roles and positions contributors held with regard to the MMR vaccine. We found that the helper role was the most frequently occurring role for both pro- and anti-vaccination contributors on Baby Center. In contrast, on Wikipedia, the judge role was most frequently held by pro-vaccination contributors, while the role of distractor was the most frequent among anti-vaccination contributors. In addition, the role of distractor was the second most frequent role among anti-vaccination contributors on Baby Center as well as pro-vaccination contributors on Wikipedia. The quotes presented are accompanied by qualitative observations to help provide context about how contributors used citations and what roles these contributors played. Our findings have important implications for research on the creation of scientific knowledge online and the general understanding of lay individuals’ beliefs about scientific controversies.

Discussion and conclusions

In this study, we first identified the sources that knowledge contributors used to legitimize their arguments in online discussions of the alleged correlation between the MMR vaccine and autism. We did not anticipate that anti-vaccination contributors would cite government sources more frequently than pro-vaccination contributors did on Baby Center and that both pro- and anti-vaccination contributors would equally cite government sources on Wikipedia. Previous research (*e.g.*, Jamieson and Hardy, 2014) has reported that sources supporting scientific findings influence people's opinions. It appears that these anti-vaccination contributors were taking advantage of statistics available on government sites to establish their credibility.

We also found that contributors play multiple roles in order to enhance knowledge and facilitate the knowledge co-production process. When it comes to establishing credibility, there is a debate about whether to trust health professionals, patients, or parents with experience (*e.g.*, Prior, 2003; Kerr, *et al.*, 2007; Langley, *et al.*, 2018). Because the majority of content shared was personal experience (Fadda, *et al.*, 2015), the role of judge was important in user-generated content sites, especially in regard to the legitimization of citation sources. In online forums like the ones we studied, users who played the role of judge emerged. As a consequence, it is important to consider who such individuals are and how they are able to play this role. Some contributors in these online communities have been active participants for quite some time and others may view these seasoned contributors as more trustworthy. Therefore, it could be difficult to assess contributors who are both new to these online communities and play the role of judge, since they have not established trustworthiness within the community. One argument is that formal policies, such as those on Wikipedia, play a crucial role to ensure that there are guidelines for contributors who act as judges. Alternatively, one can make the argument that knowledge construction online is dynamic and relies on heterogeneous actors to occur, and that formal rules hinder this process. A balance between moderating and being inclusive is difficult to achieve. Future research should examine this tension, or balancing act, more directly. Although we did not investigate these questions, our findings suggest that further inquiry may prove fruitful.

Our findings confirm the wide spread of misinformation on the Internet (Alter, 2006; Friggeri, *et al.*, 2014; Riedlinger and Rea, 2015), especially on social media (Aquino, *et al.*, 2017; Krishna, 2017). Lewandowsky, *et al.* (2012) identified three strategies to diminish information misunderstandings: 1) warning the purveyors of misinformation during the initial access; 2) repeating the act of withdrawing misinformation; and, 3) explaining why misinformation was removed. With regard to these three strategies, the online environments discussed here address the first and third. As an example of providing cautious comments regarding misinformation, pro-vaccination advocates almost always offered counter arguments when anti-vaccination advocates claimed there was an explicit link between autism and the MMR vaccine. This type of correction may help readers and other contributors to understand legitimate scientific findings (Vraga and Bode, 2017).

As with any research, this current study has some limitations. First, content analysis was limited to one topic: the alleged link between autism and the MMR vaccine. Nonetheless, it is a matter of concern because child vaccination has significant implications for public health and vaccine rates are declining in the U.S. (Fadda, *et al.*, 2015; National Public

Radio, 2015; Shelby and Ernst, 2013). Second, because the data were coded manually, the scope of the dataset is relatively small and limited to only two online communities. However, the qualitative component of our analysis provides a more nuanced understanding of online interactions; this would not have been achievable with the machine learning and natural language processing methods that would have allowed us to use a larger data set. Third, the data only came from written comments posted within these online communities. We interpreted posters' words as they were written and were unable to attain consistency when coding for neutral positions. Future research on scientific controversies and knowledge construction online should investigate "neutral actors" more directly. This limitation is also related to the study's focus solely on what is conveyed in online forums. Other researchers have proposed more integrated approaches to science communication beyond providing accurate information (*e.g.*, Longnecker, 2016). Thus, future research should use in-depth interviewing, social network information analysis, and quantitative analysis of larger datasets. In addition, other researchers can benefit from using our coding scheme to examine additional topics, such as climate change, as well as studying other online communities.

Due to the widespread use of online health information and social media, many people, such as busy parents, are likely to turn to the Internet for information, and popular sites like Baby Center and Wikipedia will play a pivotal role in informing the general public about important medical topics. Thus, it is important to understand how contributors to these sites engage in online discussions. In this paper, we scrutinized the topic of childhood vaccination and unboxed how both anti- and pro-vaccination advocates legitimized their arguments using various citations.

Our findings show that different types of actors contribute different forms of knowledge to the MMR vaccine controversy, and accordingly, play different types of roles in their online engagement with the topic. These two points suggest that certain actors have the potential to be more influential than others in not only online debates about vaccine, but also in face-to-face, non-digital contexts in which knowledge about vaccines is shared and/or shaped. Healthcare professionals are positioned to play the role of judge both online and in actual practice. They can provide patients information about vaccine, inform individuals about how to critically engage with online information, and can themselves take part in online knowledge creation, as some Wikipedia contributors did in our data. Alternatively, real-life interactions between friends or between parents and alternative medicine practitioners, who also can act as judges online, may lead individuals, for example, to consult anti-vaccination Web sites as key sources of information. Given these considerations, the foremost implication of our findings is that interventions by those who act as judges — disseminating the information they deem correct — can have a large impact on how people engage with online information, and how people act as knowledge creators in response. Examining who plays the role of judge inside and outside the realm of online discussion reveals who is positioned to influence decisions about vaccinating. Therefore, for those concerned about decreasing vaccination rates and increasing cases of vaccine-preventable illness in the U.S. and elsewhere, our findings are instructive. Healthcare professionals who seek to encourage vaccination should not overlook knowledge about vaccine that exists outside of the doctor's office or hospital. It is important for these healthcare professionals to recognize that knowledges about vaccines are multiple and constantly negotiated.

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Notes

1. Callon, 1999, p. 89.

2. Hara and Sanfilippo, 2016, p. 1,593.

3. Guidelines on proper use of medical literature. The more general one is https://en.wikipedia.org/wiki/Wikipedia:Identifying_reliable_sources.

4. w hale -dot- to is a Web site.

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