Journal of Research in STEM Education
ISSN:2149-8504 (online)
Vol 1, No 2, December 2015, PP 125-141

RESEARCH REPORT

A "Scientist" on the Radio: Understanding the Framing of STEM to the Public

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Abstract: *News media presentations of STEM (and particularly science) in various formats have been critiqued for the many ways by which they misrepresent both the facts of the discipline and the practices of the discipline and the researchers in them. Another issue is that the material is presented in a format – basically a one-way transmission – with usually little opportunity for questions by the recipients (i.e., readers, listeners, viewers, etc.) to be addressed when they don't understand something. One news media format which might allow this dialogic activity is the radio call-in show format which is structured so that the public can ask questions of a "scientist" with the opportunity for follow-up questions to address what are discontinuities in the listener's understanding. In this paper we document the processes by which listener interests ultimately end up discussed in the radio broadcast and what influences the "science" that is presented on-air. Our analysis reports the ways in which the STEM topics and content are mediated by radio station personnel, often times distorting the factual content available to the public and misrepresenting the practices of the research fields, as they engage in information management practices which are typical of opinion-driven shows (such as those on the topics of politics or sports) which are designed to create controversy and drama to increase ratings.*

Keywords: News, Media, Scientist, Journalism

Critiques of the misrepresentations of researchers and their findings in the news media are long-standing. In 1899 James H. Hyslop, a professor of logic and ethics at Columbia University in New York, wrote a letter to the editor of Science magazine in which he stated:

> "More than one-half of the interviews alleged to have been held with me were the fabrications of reporters who never saw me, and the other half omitted what I did say and published what I did not say." (p. 696).

Since then a voluminous body of research about how STEM fields, and particularly science and scientists, are presented in the news media have been published focusing both on large grain issues (such as incorrect facts) and on smaller grain ones such as writing style and the effect of specific genres of writing. Despite that research, according to Nelkin (1995) "…the style of reporting [science] has been remarkably consistent over time" (p. 1).

That we rarely hear stories critiquing how STEM fields are presented in the news media is relatively unsurprising given that the public tends to take writing about STEM topics (individually or collectively) in the news media at face value often attributing complete neutrality and lack of bias to reporters consistent with

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Bowen, G. M., Zurawski, R., & Bartley, A. (2015). A "Scientist" on the radio: Understanding the framing of STEM to the public. *Journal of Research in STEM Education, 1*(2), 125-141.

how journalists themselves would like to be seen (Deuze, 2001). This may be because the implicit training the broader public has received in STEM topics, through schooling, itself offers a very narrow, restricted view of each of those subjects (most often, in school, being presented as completely different and unconnected topics).

The practices of STEM disciplines and the production of facts within those can be parsed in many different ways. Hodson (1998) argued for the use of three broad domains for thinking about the teaching and learning of science (which, we'd argue, is equally applicable to technology, engineering and mathematics in varying degrees):

> i) 'Science'; i.e., products of science, including various laws and theories;
>
> ii) 'About Science'; e.g., characteristics of processes and products of science including, for example, that developing knowledge in science is non-linear, theory-dependent and often influenced by investigators' idiosyncrasies, that certain cognitive 'skills', such as variable control, are used, and that there are various positive and negative effects of technological products on individuals, societies and environments and ways to rectify such problems; and,
>
> iii) To 'Do Science'; i.e., expertise, confidence and motivation required to generate and communicate knowledge using methods of science and technology in unique problem-solving contexts.

Much like its presentation in the news media, school STEM subjects that the public experienced as students was most often about (i), sometimes a bit about (ii), and rarely about (iii). Hodson (2003) himself later modified his schema to include "Technology" with science, and to add a fourth dimension he considered important – "Engaging in sociopolitical action". It is this latter dimension which a critical analysis of news media provides us particular insight into, as it is the socio-political aspects of STEM disciplines – often presented in the form of "scientific" controversy – which constitute a large part of news media representations of STEM issues (consider such topics as nuclear energy, immunization, global warming, acid rain, pollution, and so forth). Elsewhere we have argued that the traditional approach to the presentation of STEM topics in the classrooms influences how the public engages in these sociopolitical issues because their expectations about how science is done and communicated, as portrayed in the classroom when they were students, is not reflected in the "science in the making" (Shapin, 1992) or "technology in the making" presentations of issues such as climate change (Bowen & Rodger, 2008).

For most of the public the news media is a significant source of information about STEM issues (and particularly science issues; Boyes & Stanisstreet, 1992; Dispensa & Brulle, 2003; Lewenstein, 2001; Schibeci, 1990) where it plays a significant role in shaping the discourse on socio-political STEM topics such as climate change (Boykoff, 2008; Wilson, 1995) influencing "both the public's knowledge and attitudes towards science." (Pellechia, 1997; p. 63) News media are the most frequent source for learning information about science/STEM topics (Miller et al, 2006; Nelkin, 1995), and 80% of adults obtain their science information and science learning from local television broadcasts.

The stage against which this news media critique can be held is the view that journalism holds of itself. In a review of the literature a decade ago, Deuze (2001) identified the ideals to which journalism holds itself:

- Journalists provide a public service;
- Journalists are neutral, objective, fair, and, thus, credible;
- Journalists must enjoy editorial autonomy, freedom, and independence;
- Journalists have a sense of immediacy, validity, and factuality;
- Journalists have a sense of ethics and legitimacy.

Even if these ideals were truly held to in their entirety there would still be reason to be concerned about the use of news media in the classroom to teach about STEM, if they are not being held to then there would be even more reason to be concerned. Fairclough (1992) warns that the media wields enormous power in its discourse and that understanding what it disseminates to the public as the ideals of the news media deteriorate

(Deuze, 2001, Zurawski, 2011) is to be ignored at our peril. It is clear from this that a critical examination of STEM topics in the news media and how they are presented to the public is warranted.

STEM Programs in the United States

There is a broad and detailed academic literature on the news media and issues with their presentation of science and scientists. We will start with a description of the writing practices of journalists, how they differ from academic writing in STEM research, and what the implications are for that with respect to the representation of research.

The following discussion often focuses on "science" (in contrast with the various STEM disciplines) and how it is presented in the news media because the idea of STEM is a more recent creation and past literature (a) past academic literature doesn't necessarily distinguish between science, technology, engineering and mathematics in how it defines "science" in its analyses and, (b) news media typically focuses on more traditional "science" in its discussion (i.e., physics, astronomy, health sciences, climate change, pollution) and less on the other aspects of STEM.

How Journalists Tell Stories

No matter which type of news media format is being used – radio, television, print, web page – reporters generally structure their story in the same way. The standard approach in journalism for telling a story is to use the opposite approach to that which we learned in our language arts schooling, and which is similar to that in science, where one starts with the context for the story and builds, through various stages, towards a climax at the end of the story. In science/STEM academic writing for journals that progression generally involves – in order – a literature review, a statement of a research question, a described methodology, a description of the data that was collected, and then a discussion of why that data was important and what was learned from that. In STEM academic writing this sequence is important as it helps build and reinforce the credibility of the findings and conclusions.

Journalists approach their writing in a completely different way than we were taught to write in language arts classes in school. They use an approach referred to as an "inverted pyramid" where the story starts with the main information and then context/evidence is laid out in a narrative below proceeding from the most to the least significant information (see Scanlan, 2003 for more details). In addition to that, journalists also provide little coverage of some important aspects of STEM inquiry such as the methods used in the investigation (thereby misrepresenting important aspects of the nature of science) and they use a narrative style adopting a "sentimental language" with metaphors and analogies to describe the world. This narrative approach has been found to have a high appeal to a readership (Halkia & Mantzouridis, 2005) but along with the missing descriptors misrepresents the practice of researchers as they work against "summative or comparative analysis that is necessary for evaluating the merits" of that or competing academic research work (Charney, 2003; p.237).

Part of establishing the credibility of a "science" fact claim lies in the detailed description of the methodology used to establish the piece of evidence. Yet, news media articles about STEM investigations "frequently omitted methodological and contextual information [of the science studies], features most often mentioned as critical for a complete journalistic account of science." (Pellechia, 1997; p. 49) and this lack of a methodological description has been also noted by others (Dimopolous & Koulaidis, 2003; Bucchi & Mazzolini, 2003; Einsiedel, 1992).

Apart from the structure of the piece itself, journalists also construct their story in a way that is the opposite of the approach taken in STEM subjects in a different way. Figure 1 illustrates the two different story approaches. Journalists tend to write a science story by referring to an "expert" who is talking about an idea and even if they are talking about a collaborative research paper they will often only refer to a single researcher when discussing the findings (Figure 1 top half). Journalists are encouraged to write about "A person, doing

something, for a reason" (see Bowen, 2011) and when writing about science this means that the story often focuses on one individual researcher despite the number of other researchers who may have participated in various ways – directly or indirectly – in creating the knowledge claim (in fact, journalists will deliberately ignore the other researchers in the writing, even against the specific wishes of the person being interviewed (unpublished data; Kim P. Good, pers. comm.)).

STEM researchers, on the other hand, write papers which are about an idea or ideas which they subsequently support by referring (a) to the evidence that they collected and (b) to the collection of authorities who contributed to developing the knowledge claim(s) that the research article is about (Figure 1 bottom half). Thus, the writing approach engaged in by journalists often misrepresents the communal aspect of how STEM research is often done (see Latour & Woolgar, 2013) as it is presenting research as if it was done by individuals as opposed to collectives of researchers over a long period of time.

The use of only a single source to discuss (and more importantly, support) a STEM idea/knowledge claim/finding (as portrayed in Figure 1) lends itself towards a very common journalistic practice, and that is the way in which journalists provide "balance" to a story by first presenting the story as having two "sides" and then choosing one individual to speak to each side of a story. For instance, between 1988 and 2002, 88% of newspaper articles on global warming science had a "denier" perspective included in them (Boykoff & Boykoff, 2004; also see McBean and Hengeveld, 2000; Curtis, 2007). In general this approach does not work well for a great number of STEM topics, particularly those involving the environment, animals, new technologies, etc (Myers, 1996)…in other words socio-scientific issues. The practice of providing "balance" is intended to "display objectivity" and originates in British parliamentary democracy for which political issues were seen as "having two, and only two, sides" (Myers, 1996; p. 34/35). Yet, what it accomplishes is a misrepresentation of some of the very core ideas of STEM/science reporting issues by reporting them as black or white without any room for nuance or grey areas (Maille et al, 2010).

One core idea that this for/against presentation misrepresents is fundamental to the very nature of how STEM knowledge claims are constructed. STEM research is not a process whereby a definitive "answer" is produced but is, rather, a probabilistic endeavour where researchers produce understandings of "likely" answers. News media, however, portrays STEM (and particularly science) investigations as producing "certainty" (see Collins, 1987) ignoring that at its core scientific research is a probabilistic enterprise. Journalistic "balance" comes about from first dichotomizing scientists into "for" and "against" communities and then treating those as if they lie at extreme poles of absolute statements as opposed to the grey areas involving nuance and probability that characterize science. This artificial creation of balance exaggerates the debate and underplays the consensus (Wilson, 2000; p. 11). Given the desire of journalists to create dramatic tension in their work for narrative purposes (as would happen in fictional novels and stories) they would have little tendency to frame their representation of scientists' work in other ways. Even from this basis alone teaching students "about [STEM] science" using news media distorts their understanding of STEM science as a practice and how it establishes factual claims. An examination of discussion threads appended to news articles in science makes it clear that this distortion of the practice of science and how it derives its fact claims by the news media is not understood by a large number of the reading public (Bowen & Rodger, 2008). This misunderstanding leads to an "all-too common popular view [amongst journalists], if scientists cannot produce definitive results, then they are not doing their job properly" (Charney, 2003; p. 237).

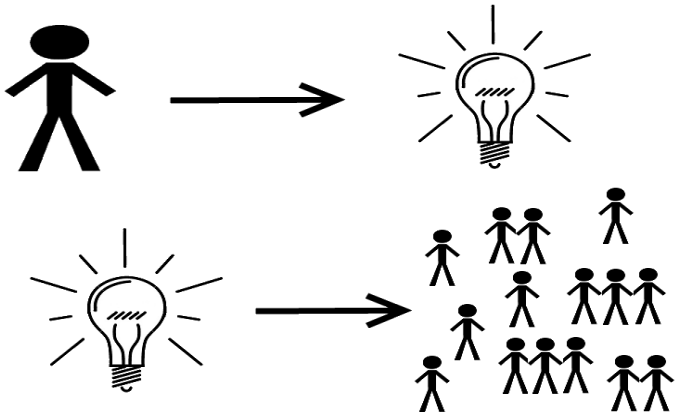

Figure 1. *The top half of the diagram illustrates how journalism portrays science research ideas/facts/discoveries as if they extend from a single individual. The bottom half of the diagram illustrates how writing in STEM science is about an idea which is buttressed using various individual and collections of authorities (Donald, 2012). This "community" aspect of STEM discovery is often ignored in journalistic writing.*

Who/What Influences Which Stories are Chosen

At one level, narrative factors are what drive journalistic attention (McComas & Shanahan, 1999) such that "When journalists see the possibility of narrative interest, their attention goes up." (Shanahan & Good, 2000; p. 294). In other words, the possibility of being able to tell a good story drives their interest in a topic. "The central assumption of the popular press journalists is that unless the science which they cover can be seen to be relevant to the reader's daily life and concerns, it is not suitable for coverage." (Hansen, 1994; p. 129) Yet, one needs to recognize that despite their claim that the news is a "mirror held up to society, it is actually a highly selective account of events. News is a version of reality shaped in significant part by journalistic norms and conventions. In addition, journalists are shaped by pressures by those who have a vested interest in the topic or the newspaper/magazine" (Dispensa and Brulle, 2003; p. 81).

Irrespective of the type of journalism – print or broadcast journalism – there is an "editor" or "producer" of some sort whose job it is to control what stories journalists are doing and how they are going about structuring them to be presented to the public. It is uncommon for journalists to be able to make their own choices without considerable input from their editor(s) or producer(s). In those instances they might receive direction to cover one story or another without any insights into why the choice was made, or it might even run against their instincts about what the best story would be (see Bowen (2014) for detailed examples of this).

Overall, ideology determines what is considered STEM news by journalists and producers/editors and the interpretation of the information is strongly entangled with ideological viewpoints (Carvalho, 2007). This results in a narrowing of STEM science topics discussed in the news media, with a general focus on issues that affect the daily lives of individuals (Hansen, 1994) such as biomedicine (Bucchi & Mazzolini, 2003), health issues (Almeida, 2013; Pettersen, 2005; Hansen, 1994), behavioural studies (Clark & Illman, 2006), and environmental stories (Einsiedel, 1992).

That these issues arise are unsurprising given that the science (and other STEM area) backgrounds and understandings of journalists (and their editors/producers) writing about science are weak. Generally news journalists do not have training in science (Hansen, 1994; nor do some consider it to be necessary, see Bowen (2014)) and generally they have notable gaps in their knowledge in the science areas they write about (Pettersen, 2005; Wilson, 2000; Maille et al, 2010) as well as having a "restricted" knowledge of statistics and scientific discourse and the very "nature of science" (Pettersen, 2005).

The touchstones of STEM research – "uncertainty, probability, an uncertain time frame, and the frequent pursuit of knowledge for its own sake" – run against the journalistic preference for "certainty, fewer caveats, shorter time lines, and the entertainment of audiences" (Einsiedel, 1992; p. 100). It is hardly surprising, given the above, that popular media accounts of STEM research "may breed cynicism about the scientific community itself" (Charney, 2003; p. 238).

The Public Interest in the Communication of STEM Issues

In this review we've identified many areas of considerable problem regarding communicating science to the public. How might we redress issues communicating STEM to the public while at the same time better understanding the public interest in STEM research itself?

In the following section we examine a radio call-in show (called "Science Files", even though the questions from the public that it addresses range broadly across STEM topics) where an expert "guest host" (who has a quite broad and encyclopedic background in science, technology and mathematics issues) joins a regular morning show host taking STEM questions from the general public and providing answers to those questions. Our interests in this project include (a) documenting production practices within a broadcast facility to understand how these mediate and influence the "science" available to the public in the broadcast itself (having documented elsewhere how practices apparent "outside of the studio" during the public broadcast/presentation of science influence the view of science/science claims available to the public; Bowen (2014)), and (b) analyzing how the interaction between the hosts and those calling into the station frame and present science to the listening public. In the sections below we first describe the process by which STEM "topics" enter into the discussion on the radio call-in show. Then we briefly analyze three of the radio broadcasts to examine the types of questions asked by the callers and how those arise.

Data Sources and Methods

In our examination of the call-in show on a local commercial radio station (serving a market of about 1 million potential listeners) we have used two information sources (one triangulated) for the analysis conducted herein. The first author (Bowen) obtained a journalism degree as part of an academic sabbatical five years ago. This provided him the opportunity to participate in radio news broadcasts, including on science topics, as a student journalist which helped shape his perceptual lens examining the call-in show in this study as he observed half-a-dozen of the radio broadcasts from the producer's booth (and later subsequently acted as a co-host himself with related science radio call-in show). The second author (Zurawski) is a journalist with a broad science background (particularly in physics, meteorology and weather forecasting) and considerable knowledge about other STEM issues. Amongst other accomplishments he has produced three broadcast television series (one science, one for math and one in weather) for children, dozens of TV science documentaries (broadcast on Discovery Channel, ZDF, VisionTV, etc), written popular press books on both climate change and the news media presentations of science, and is in ongoing demand to give public talks on science, STEM and related socio-political issues. This author is the "scientist/guest" host in the radio broadcasts described in this paper, who addresses the public STEM questions and is the resource used to provide detailed descriptions of the practices engaged in to produce the call-in show. The involvement of both authors in news media journalism, the area of this paper, and the second author's involvement as the science "guest" means that this work falls within the realm of "participatory research" (Bergold & Thomas, 2012). Conversations and email exchanges between these two authors framed the description of the processes involved in the radio call-in show production (and the third author acted as a "critical friend" in our final analysis of our documents and conversations and in the production of the final paper).

In addition, we downloaded publicly-available recordings of the on-air broadcast and transcribed and analyzed three of the broadcast radio call-in shows. . The analysis was conducted to provide insights into the construction of STEM understanding and research practices through the interaction of the caller, the morn-

ing-show host, and the "scientist/guest" host. Topics and questions (asked by those calling/writing in to the show) were then discussed to provide insights into the public interest in and understanding of STEM issues.

It is important to note that comments discussing the host or the producer are made in full recognition that they are serving particular roles within the broadcast of a radio show. That we may report that these roles and how they are enacted may not well represent STEM disciplines and the knowledge developed by them or STEM issues is not a criticism in any way of the individuals enacting these roles because they are acting (as we report) according to common journalistic practices, instead we are highlighting issues with how those common journalistic practices, that may well suit sports, politics or regular news reporting, seem to conflict with the presentation of STEM disciplines and issues.

Data and Discussion

Background of the Station and Call-in Show

The call-in show was broadcast (as well as streamed online) on a commercial station to the local market twice each week during regular hours having a consistent host on Monday to Friday. This regular schedule allowed listeners to plan to listen to the science call-in show or to plan to call, email or tweet in a question for the show. The call-in show was promoted in "blurbs" the day before and morning the morning of the show before it occurred. Once the show started and the science host was introduced the phone number, email address and twitter handle for the show were provided and listeners were encouraged to call in with their questions.

According to the Bureau of Broadcast Management (which conducts surveys of listenership twice a year) the station had a typical listenership (when the study was conducted) of around forty thousand listeners and the science call-in show was at or near the top of all of the local station programming with regards to number of listeners, caller volume, internet responses, and web listenership.

The show itself was staffed by four people (there was also a "news" broadcast person who reads the news in a short broadcast on the "halves" (i.e., at the top and bottom of the hour), with brief commercial breaks on the "quarters" (i.e., at fifteen minutes before and after the hour). The other staff were: the show "producer" who runs the technical equipment supporting the show (i.e., microphones, controlling the information and timing screens, running advertisements, promotional audio, weather forecasts, pre-screening choosing which callers get on air, and other blurbs) from the control booth, the show "radio personality" (i.e., regular morning show host) who ran a 3 hour news and information discussion show (which includes interviews and call-in components) on weekdays, and the "scientist/guest" host who answered the questions raised during the radio call-in show segments during the week. Each had responsibilities specific to the running of the show (Table 1). Both the regular show host and the producer spend about half their work day preparing for the show, including lining up callers and topics to be discussed as part of the show (if there were no calls the host and "scientist/guest" host discuss topical science issues researched in advance). The producer works in conjunction with the show host to "create" topics deemed to be of interest to the station, timely topics breaking in the news, and local issues for the local market.

Table 1:
Roles of Participants in Radio Call-in show.

"Caller"	Show Producer	Regular Show Host	"Scientist/Guest" host
Asks initial question Elaborates question if show guest requests it, or responds to the answer May participate in conversations with the two hosts if the producer and regular show host allow it.	Takes calls Screens calls (removing callers who don't have a question, who want to "rant" on a topic, or who have non-science based questions (these were typically "known" callers with "issues")) Finds out topic(s) of accepted call(s) and passes name of caller(s) and topic to show host electronically* May conduct web searches on topic to forward to host* Make sure show sticks to timings	Be entertaining and engaging Stick to timings Make sure there is no "dead air" Act as a foil for the "scientist/guest" host Repeat and repeat things (radio broadcast is unlike other media in this regard) Moderate the phone-ins Raise follow-up questions to get the "scientist/guest" host to elaborate on his explanations and provide more detail Have own topics of discussion for "scientist/guest" host in case there are no call-ins.	Answers questions as accurately as possible Reframes questions if necessary Be entertaining and engaging Have his own topics of discussion in case there are no call-ins. Creates dialogue and banter with host

*Usually by email message, sometimes by voice over earphones.

How "Topics" Reach the Airwaves

Topics discussed on-air emerged from interactions between the caller (who could contribute questions using a phone call, by email, or by tweeting), the producer, the host and the "scientist/guest" host. Not every question asked by someone calling-in made it to air, and there was often a considerable influence enacted by the show producer and host on what was discussed by the "scientist/guest" host on-air (at other times there was none, as the topic was raised and discussed by the "scientist/guest" host himself).

The following describes how the show began. The call-in show was preceded by a news break on-the-hour and then the "scientists/guest" host was introduced. There was then often "banter" between the host and the "scientist/guest" host and during that banter, varying in where it was introduced, was a request for listeners to call-in with questions. Despite the other ways listeners could contribute questions (i.e., email or tweets) phone calls which allow interaction between the caller and the "host" and "scientist/guest" host appeared to be the preferred method of having questions asked. Therefore, the preferred hierarchy for discussion appeared to be (a) voice/listener call-ins, (b) discussion topics selected by the host or the "scientist/guest" host, (c) then emails or tweets submitted by listeners. Occasionally (c) reflects questions submitted during the week between broadcasts of the science call-in show.

When a phone call was received it was first "screened" by the producer – who was at a control console in the control booth – who evaluated whether the caller should be allowed on-air or not. In the few circumstances observed where a caller was not allowed on-air it appeared to be because the question was not really a science question or because the caller was a repeat caller who had caused issues when calling in the past. Based on the reactions of the producer (and later, the host) it was clear that some callers were repeat callers.

After the producer determined that a question was suitable for broadcast, the question topic was then communicated to the host (usually by electronic message (using a messaging tool like email which was part of the production management system) or by voice communication to the hosts headset (which was not audible

to that of the "scientist/guest" host)). Depending on call volume or other show management responsibilities, if they had time the producer would then look up websites on the topic(s) (which had been forwarded to the regular host) and if any relevant URL's were found they were emailed to the host (but not the "scientist/guest" host, who was expected to respond to the call-in question extemporaneously).

Often at the start of the show there was no listener phone calls received by the show producer. Emails and tweets containing questions submitted by listeners went directly to the call-in show host. Thus, for discussion the host then could choose from any emails or tweets he'd received between show broadcasts, he could raise a question which he'd discussed with the "scientist/guest" host before the show was on-air (in these instances it may be a topic proposed by the "scientist/guest" host himself), he could raise a topic suggested by the producer (for which online resources/information may have been provided to him), or he could choose from topics he'd selected n himself prior to the show. These latter topics were important in laying the foundation for an engaging show. The host would have a reserve of what he considered to be "hot button" STEM news topics culled from the print (and other) news and other sources designed to kick-start the callers, tweets and emails. Often these topics would cover typical denier/contrarian STEM controversies designed to cue audience response and participation. Examples of the line of questions/topics to discuss with the "scientist/guest" host might include recently published articles by "anti-vaxxers", or climate change deniers or creationism tenets. It was clear, watching the main host, that he viewed his role as one which involved introducing, encouraging or increasing "drama" (a common role of news media).

It was notable that questions which were chosen by the regular host were ones which he had sufficient time to prepare for in advance by researching them online (or having websites provided by the producer) allowing him to engage in meaningful and seemingly knowledgeable dialogue with the "scientist/guest" host when the questions were asked. Even as the dialogue was taking place between the caller and the "scientist/guest" host, the main show host would search Google or Wikipedia on his computer to garner additional information on the question or topic and then chime in as the conversation progressed, to bring himself into the question discussion (between the caller and the "scientist/guest" host), often with the intent of continuing the journalistic pro/con adversarial polarization to "spice up" the dialogue and raise the drama level with the goal of raising listener engagement (strategies for doing this, such as choosing particular "verbs of saying", are described in Bowen (2014)). This was the case especially if the show host thought the question asked by the caller was too "low key" (i.e., having low listener interest or not being dramatic enough to be engaging).

Questions and topics raised by the show host derived from the following sources:

- provided by the "scientist/guest" science expert (in advance of the show).
- provided by the producer (who would email him links to science topics the producer thought were interesting).
- derived from emails/twitters from listeners (sometimes identified as coming from a tweet/email by the host, sometimes not).
- from the host's own research about science topics before the show reflecting his own interest as well as being topics he thought would be engaging and interesting.

In contrast with the host, the "scientist/guest" host was often unaware of what question/topic was going to be introduced and was expected to engage it without any opportunity to prepare. In addition, unlike the host who had access to a computer which was actively used by him throughout the broadcast, the "scientist/guest" host did not have a computer in the broadcast booth and was expected to answer the questions or engage the STEM topics extemporaneously.

In most cases the banter between the host and "scientist/guest" host was designed by the host to pander to the perceived notion that there must always be a two-sided dichotomy when discussing STEM issues (similar to the "balance" approach used by journalists as discussed earlier in our introduction). Where there was

no immediate question or caller/email or tweet the host would raise a piece of "topical" STEM "news" which was presented as a dichotomy with the host supporting one view and the "scientist/guest" host the other, often opposite, perspective. For instance if a headline in STEM news was about the prospect of the existence of life on other worlds, the "scientist/guest" host would be asked his position and the host would immediately take the other side in an adversarial fashion to provide the perceived balance prevalent in journalistic practice. The issue of the actual STEM content and how the host might skew the perception of the topic in the public mind to provide these polarized decisions was rarely if ever discussed between the host and the "scientist/guest" host. This process extended into all areas and fields of STEM, from Climate change to anti-vaxxers to Darwin vs Creationists.

Using this adversarial approach it was a common practice for the regular host to attempt to undermine and find some fault, no matter how minor, with the explanations provided by the "scientist/guest" host. The positioning of trying to undermine science/the scientist in all areas discussed was prevalent throughout the hour, in an almost game show manner. The task of the host was implicitly to be the foil against STEM findings and any researcher. The regular host's language and discussion was often not around how to clarify or make the STEM information understandable or discernible to the listener, but was more of a "contest" between STEM research and the public, where the goal was to "stump" the "scientist/guest" host and thereby "prove" the fallacy of scientific method. Common statements throughout the run of the show to that point have been "How do you know?" and "You think you are so smart" (the latter clearly an attempt to frame the "scientist/guest" host as an elitist). In fact, early on during the show's inception there was a substantial portion of the show dedicated to "stumping the science chump" where putting the "scientist/guest" host into the position of saying "I don't know" was a goal of the show host.

Insights into the Public Interests in Science through Call-in Questions

Often, questions asked by the callers (or submitted electronically; note that we did not have access to the questions submitted by email by listeners to fully comment on this) appeared to be "one-offs" in that they did not derive from earlier questions or discussions between the show host and the "scientist/guest". Callers frequently appeared to struggle with framing and centering their question when they were asking it and they often left their discussion/question/sentence/voice trail off leading the "scientist/guest" host to broadly discuss the topic they had raised with the caller, or the host, asking further or elaborative questions during the conversation. It was notable that in the three shows chosen for analysis that all callers appeared to be male (despite a listenership that was roughly split 50-50 between males and females (Bureau of Business Management) callers were rarely female with this host) having male names, using male referents, and having stereotypical male vocal patterns and tones.

Examples of the types of questions submitted by listeners are found in Table 2. Of the three broadcasts which were part of this study there were six, four and seven listener participants in the hour-long broadcasts (with short news and advertising breaks four times in each broadcast hour). In some cases the listener asked a single question, listened to the response, and then thanked the "scientist/guest" host and hung up. In other cases there were extended dialogues with follow-up questions between the caller and the "scientist/guest" host.

Table 2:
Examples of questions asked by the listeners.

[Phone in] Raw meat, if it is cured as in Proscuitto or salami it does not spoil. But boil it and it spoils. Why?
[Emailed in] Since the moon is held in place by the pull of the earth and the pull of the sun, would any change to the weight, shape or size change its orbit/distance from the earth? If so, what would be the effects if it moved closer, and also if it moved further from the earth? I ask this because every now and then there have been discussions about mining the moon for resources and that could, over time, eventually change the moon. I hope this isn't too confusing. I look forward to hearing what you can tell me about this.
[Phone in] I'm trying to create a science experiment here. Basically, I'll give you a little story about what I'm trying to accomplish here. I was watching this show called "Brad Meltzer's Decoded" and they had some expert there talking about magnetic vortexes. So they had this so-called expert on magnetic, I'm not exactly sure how you'd become a certified expert on magnetic vortexes, but he claimed to have one. A miniature one. He had a 3 magnets he had (word unclear) he had put into the shape of a star and basically the effect he was saying if you stand at the edge of the vortex, two people, standing opposite each other, one will appear to grow taller and one will appear to shrink. Now they re-created the effect on TV. The people that took part in [cell phone cutting out] I put two magnets...[voice faded out]
[Emailed] Why are there so many sinkholes in Florida? Any idea?
[Emailed] Is quicksand real or is it an invention of bad 70's television writers?

Question topics were from a broad range of science domains (although there was a somewhat greater tendency towards physical science/astronomy/engineering topics, possibly reflecting the academic background of the "scientist/guest" host) touching on topics (across many shows) exceeding those in this study, all of science, math, engineering and technology and even psychology and sociology (Zurawski, Bowen; unpublished data). In addition to the variety across subjects, the topics raised by listeners or the show host were often ones which could be considered "sensational" or "dramatic". This effect was exacerbated by the host (as described earlier) participating as a "foil" or challenger for statements by the "scientist/guest" host – who was answering the question asked by the caller – in that the regular show host "polarized" or split topics into "for/against" perspectives in what was an obvious attempt to raise the drama(tic) level. Thus, listener questions, which were seemingly submitted for informational purposes, were turned into "debates" by the show host, in many cases obfuscating the factual responses that the "scientist/guest" host was attempting to provide in response to the question.

Based on their comments and the interactions with the hosts, the questions asked by the listeners appeared to derive from many sources (see Table 3).

Table 3:
Apparent sources of questions from the listening public

Own "everyday" experience
From previous radio call-in show topics (host & science expert discussions)
Newspaper and other news items
TV/Movie entertainment
Past school experiences

Finally, occasionally the conversation between the show host and the "scientist/guest" host influenced the questions asked by the listeners. For instance:

1. Host and "scientist/guest" host discuss "dreams" for 10:20.
2. Phone in questions from callers (4 in total) then deal with "dreams" for the next 7:30.

Following the host/"scientist" discussion of dreams listeners the listeners phoned in with the follow-

ing questions about dreams and dreaming (names below are pseudonyms):

- Corey (male): While I was just wondering, you were talking about dreams and stuff, anyone who has quit smoking and drinking, mostly with smoking, you take the patch and usually you sleep with it and your dreams are so real. They totally change your everyday dreams. I was just kind of wondering how, if they did studies on it, or why that happens....
- Jimmy (male): Do animals dream, or is it something that's a side effect of the evolution of man? Is it something like as our brain got more sophisticated it's like an off-gassing type of sort of thing or do other animals all dream? And why?
- Dan (male): Why, I get a good night's sleep or whatever, but I never seem to remember dreams. That happened since I was a teenager.
- Bernard (male): I was wondering, I always dream about people and places I don't know anything about and I was wondering if you had any comment on that?

This "seeding" of the broadcast with ideas to stimulate calls from the listeners is unlike the process which can occur in the surveys usually used to understanding what science topics the public is interested in within which there are no such "prompts". As can be seen in these questions the influence of the topic of "dreams", as first introduced by the show host, provides a rich substrate for listeners to engage with a science topic linked to their personal experiences (which most of the questions reflected). It is unlikely that this sort of detail about interests in a specific science topic, such as dreams in this case, could be gleaned from a survey designed to understand public interest in various STEM topics.

From the preceding narrative descriptions of practices engaged in by the participants involved in broadcasting a science call-in show the following observations deserve highlighting:

- stereotypical, and normative, journalistic practices of creating tension/drama play-out even in a call-in show dealing with science, technology, engineering and mathematics topics
- the host often acted as an antagonist (versus as a protagonist) with the "scientist/guest" host, seemingly aiming more for entertainment and obfuscation on STEM issues rather than being informative
- journalistic practices of providing "balance" were present in the radio broadcast through the framing of STEM issues (by the host) as being polarized into opposite for/against perspectives
- science was presented in a "competitive" frame where the host was striving for "I know this and you don't" types of discussions, and this was exacerbated by the host and the producer having computers, access to the internet, and advance knowledge of the questions; which were resources not provided to the "scientist/guest" host. Pre-show preparation by the host/producer on topics unknown to the "scientist/guest" host further emphasized this "competitive" aspect.
- control of topics, and the length of engagement with the public, lay mostly in the hands of the station employees – the show host and producer – the "scientist/guest" host often had little influence on topics/engagement with the callers
- public interest in STEM issues was wide-ranging but was often somewhat unfocused in that the callers were interested in the topics, but were often unsure how to phrase their questions around those topics (as the quoted calls & emails suggest).

Conclusions and Implications

The structural design of this call-in show is typical of that found in talk radio in that it has a "caller", an "expert", a "studio host" and a listening audience (Hutchby, 1995). What is revealed in this analysis is that the producer has a role in the topics and information conveyed in the show to the host and "scientist/guest" host, and further that the producer played a role in the "antagonistic role" of the show host. The process

through which "questions" flowed before reaching the airwaves meant that the calls that reach the "scientist/guest" host to be answered were filtered first by the producer (w.r.t. phone calls) and secondly by the regular show host (who was able to filter all listener input) before the questions were actually asked of the "scientist/guest" host. This is quite similar to a process we have described previously (see Bowen (2011, 2014)) where it was an unknown producer who decided which science stories a science journalist was going to create a news segment about on a particular day. In other words, which STEM topics make it on air during the call-in show were determined in large part by people in news media without a background in science who have an eye on protecting the interests of the news media outlet itself (i.e., ratings, sales, etc), in this case of the call-in radio broadcast both the producer and the regular show host. Even in this venue of call-in radio, unexpectedly we might add, there is a buffer between the listening public and the "scientist| that mediate the STEM issues that are considered publicly relevant and of public interest. This "control" by the host of the topics and how the "scientist/guest" host and the listeners get to participate in the construction of the on-air "science" is similar to that which has been reported for talk radio broadcasts about politics (Thornborrow, 2001), although the role of the producer in screening calls and providing web-information to the host for discussion was unreported in that study. This similarity is particularly true when it comes to the asymmetry resulting from interventions by the host that limit the contributions which are possible from the other participants in the on-air dialogue, despite the contrast between the socio-political content in Thornborrow's work and the more fact-based content in the science show (which the host appeared to attempt to make controversial and polarized).

Topics often raised by the host (and sometimes by the "scientist/guest" host) often reflected the "spectacle" nature of STEM/science (Davis, 1997) so that listeners were entertained and engaged. This was emphasized by the host's use of oppositional strategies, such as "you say X, but what about Y" (see Hutchby, 1992) to polarize the conversation and develop controversy. This strategy would seem to be adopted to negate any "grey areas" and to present the STEM findings as black or white without any nuance (see Maille et al, 2010). In many ways the approach resembles that of a cross-examination in court, whose purpose is to raise doubt about the initial explanation by the witness, and in this instance to raise doubt in the explanation provided by the "scientist/guest" host. Thus, despite the "scientist's" efforts to answer questions in a straightforward manner presenting the best information available from STEM research, the listener's experience provided a considerable opportunity for them to doubt the answers provided by the "scientist/guest" host (based on the arguments of the show host) and instead adopt an understanding about the issue quite at odds with the current scientific understandings. This emphasis on non-scientific explanation is similar to that which is present in journalistic practices in print media (Dearing, 1995). These practices have considerable implications for what the public hears and learns about STEM disciplines (and how they frame their understanding of those disciplines), how science information is conveyed (combatively, if the show is taken as an example), and how knowledge is conceived and grows (in a polarized, oppositional manner as modeled in the show). Given this, it is worth asking if call-in shows such as this one actually do STEM subjects any service at all, or do they cause more issues in public understanding than they resolve?

One positive role that a "scientist" in a phone-in show can serve is as an effective interpreter of language contrasts between the use of terms in STEM fields and that which is in "general usage" by the public. Somerville and Hassol (2011) identified numerous words – such as bias, theory, and manipulation – that had different meanings to the general public than they would to researchers. Discussion of these terms by a "scientist" affords the opportunity for these differences to be discussed, and the dialogues between the caller or the host and the "scientist/guest" host provided a greater opportunity for these different understandings of terms to come to the fore. This might well be particularly educative for the listening public as there is evidence that call-in radio shows can lead to the listeners actively participating in the construction of meaning (Tankel, 1998).

Nevertheless, there is almost an "inevitability" for the existence of communication problems between the STEM research and the public (Neidhardt, 1993; p. 348), including journalists, because of the increase in complexity of language in research that is occurring (Hayes, 1992). This is considerably problematic as "when people cannot understand, they have to believe. And whether they believe or not is a matter of trust." (Nied-

hardt, 1993; p. 348) which means that when trust is lost, so is the acceptance of the STEM research. It is easy to see how this would happen in a context where incorrect information is presented (such as when the host framed science knowledge oppositionally against some type of "denier" claim raising skepticism about the established science itself) because of a lack of understanding by the journalist of the STEM research itself, and a lack of time exists (through what is arguably a cultural practice of journalism; Bowen (2014)) to allow the journalist to move beyond the "instant expert" role that they both are put into and accept (ibid) so that they cannot actually developing expertise in the area. In the radio call-in show the host clearly demonstrates this "instant expert" approach of journalism through the role he takes in the show whereby he portrays himself as knowledgeable about the topic under discussion through his (and his producer's) use of the internet on-the-fly to frame his discussion with the "scientist/guest" host.

The heavy prevalence of male callers (there were female callers in other shows that were observed, but they had a very low prevalence) is not atypical for call-in shows. Tannen (1990) provided a similar description of a call-in show which had a similar 50-50 split in listenership, but which even on topics where one would think there would be a high female participation (i.e., abortion) there was low (~10%) representation of women callers. Various explanations are offered for this, notable amongst them are the suggestion that "fewer of them call in because to do so would be putting themselves on display, claiming public attention for what they have to say, catapulting themselves onto center stage." (Tannen, 1990; p. 288). Thus, it is actually difficult to draw conclusions about what the "public interest" in STEM might be when almost half of the potential "public" are (supposedly) choosing not to participate in public call-in shows (Note: a recent change in the call-in show to a host with a less confrontational style has, reportedly, led to an increase in female callers. This has interesting implications.). This limits the utility of studying questions asked in shows such as this to discern any specifics about what STEM issues the public might be interested in.

The current, and ongoing for some time now, decline in specialist STEM/science journalists (Mooney, 2010; Wilson, 2000; Boykoff & Mansfield, 2008) offers little hope that the quality of STEM journalism will improve, suggesting that the problems detailed in past research studies of science in the news media will likely do nothing but increase. The teaching of journalism practices in journalism schools can contribute to the very problem of news media presentations of STEM/science discussed above (see Bowen, 2014) and changes in how journalists view themselves and their role in society also leads to doubt that science journalism will improve. This change in view includes a moving away from the "ideals" discussed earlier (from Deuze, 2001) to such an extent that "notions of objectivity, ethics, detachment, and even the public service ideal" are going "down the drain" (Deuze, 2001; p. 10) such that journalists do not see themselves as having responsibilities to educate the public about STEM issues, but rather that their job is one of providing an "entertaining coverage of science" (Hansen, 1994; p. 130; also Bowen, 2014)

A radio call-in show offers many opportunities for the public to develop their understanding of STEM findings and research. However, our study suggests that to accomplish that it would have to adopt a different structure than that which is used for other subjects such as politics. The for/against polarizing approach adopted in this show poorly reflects the structure of science presented by Hodson (1998, 2003) and has the potential to generate as much misunderstanding about STEM research as it does understanding of it. It is clear to us that these shows require a host and a producer who need to understand STEM research and its practices as much as they are as they need to be familiar with the needs of journalism and broadcasting (specifically the need to generate interest and engagement by their listenership). In other words, in this show the seemingly limited knowledge about STEM research of the producer and host biases and distorts the very STEM information the "scientist/guest" host is able to present to the public (a mediating process also documented elsewhere in television reporting in Bowen, 2014). We consider this to be problematic as the intent of the "scientist/guest" host is to promote STEM (and particularly scientific) literacy through his participation in the broadcast and in our view the structuring of the program (through engaging in "typical" call-in show and journalistic practices) restricts that.

Overall, we feel it is important to note that there is an interaction effect between news media and what is learned in "school science" about STEM disciplines and their practices. In general school science develops an understanding of science that the public "has" when it leaves school. Traditionally this has been a very structured or definitive view of science that little resembles science as it is engaged in by scientists (see Bowen & Rodger (2008) for how this perspective plays out when discussing global warming issues in news media forums). Thus, as adults, the public encounters the news media (re)presentations of STEM issues in news media, even in science call-in shows, which also offer a description of research and knowledge growth in STEM disciplines that also doesn't well reflect STEM research as it is practiced. Ultimately, the news media presentation of STEM issues, through the mediating impact of the show host (at least in this case) and producer, reinforce the distorted perspective of STEM practices and claims that were originally developed in the traditional science teaching experienced by much of the public in their schools. This would seem to arise because the interests of the commercial radio station lie in "entertainment" as opposed to "education" or accurate information and in that they are treating STEM topics no differently than any other topic these days, whether it be sports or politics.

Finally, it needs to be noted that this is a study of a call-in show in a "particular" broadcast market (perhaps not reflective of others) and examines the practices of a particular host and producer. Although the general structure of the show compares with studies of other call-in shows, the actions of this particular host may well have influenced both the actions of the producer and the way in which the public callers engaged with STEM issues with the "scientist/guest" host; in other words no broad conclusions can be drawn from just this study. What was obvious, however, was that there was considerable interest in being able to ask STEM questions and have them addressed by someone who was presented as an authority. However, this interest often dealt with "personal" topics (i.e., dreams) and within that perhaps lays a lesson that higher engagement in science derives from allowing individuals to find "personal" connections to science topics (such was also concluded in a completely different setting by Cakmakci et al., 2012).

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