Key Findings: The (Very Limited) Evidence Base for Basic-Science-Specific Science Communication in Key Communication Journals

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We used a combination of keyword- and human-coding-based strategies to identify and characterize the degree to which four key science communication journals have included research articles focused on the communication of basic science (N = 2,386). These journals included *Public Understanding of Science*, *Science Communication*, the *Journal of Science Communication*, and the *International Journal of Science Education, Part B: Communication and Public Engagement*. Our intention is to give those interested in basic-science-related communication the ability to speak to the degree to which an evidence-based 'basic science communication research literature' exists within core science communication journals.

Our tentative conclusion is that less than 5% of the available research provides substantive quantitative or qualitative evidence that specifically speaks to communication in the context of basic science. An additional qualitative review of the basic science-focused articles that included quantitative or qualitative data further suggests that there is little evidence of a shared focus within the available work. Further, the focus of the available articles was typically on a narrow range of potential communication outcomes such as others' science knowledge, risk/benefit beliefs, and emotions. There was also only limited connection made between these types of outcomes and potential longer-term goals such as increasing support or acceptance for funding/policy or building long-term, positive relationships between scientific communities and others. We also saw no attention to 'basic science' as a key organizing concept in the research.

Two additional case studies—reported separately—explore astronomy- and neuroscience-focused communication research in more depth. The case studies' conclusions are consistent with the overall findings reported in this summary but also highlight how researchers in specific areas may focus additional attention on issues of special relevance to their topic. For example, neuroscience-focused research appears to put substantial attention on the potential misuse of imagery as a tool of persuasion, whereas the ability of astronomy communication to evoke positive emotions about science and serve as a tool for increasing youth attention to scientific careers seemed especially important to astronomy-focused communication researchers.

The conclusion we draw is that there is a substantial opportunity for research and discussion related to basic science but that such discussions should recognize the value of looking beyond basic-science-focused scholarship. One path forward would be for organizations or groups to explicitly identify shared questions that they would like answered.

In the language of strategic communication, this path forward would involve people in the basic science community identifying the long-term goals they hope to achieve through communication (e.g., ensure funding support, increase the diversity of youth choosing science careers, identify promising research paths) and then building research programs aimed at better understanding the nearer-term objectives (e.g., factual knowledge, risk/benefit beliefs, normative beliefs, self-efficacy beliefs, trustworthiness-related beliefs, specific framing and emotions) and tactics (e.g., changes in behavior, message, style/tone, channel, and sources) that might help the basic science community achieve its goals. Clear identification of goals and objectives would also help with identifying existing theories and theoretical gaps around which to build new research. This perspective is further explored in a companion essay on the topic.

Summary Report: The (Very Limited) Evidence Base for Basic-Science-Specific Science Communication in Key Communication Journals

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Introduction

This report summarizes sponsored research into the degree to which four key science communication journals have published substantive, data-focused research on communication activities related to basic science. These journals include *Public Understanding of Science*, *Science Communication*, the *Journal of Science Communication*, and the *International Journal of Science Education, Part B: Communication and Public Engagement*. These journals were selected because they represent key peer-reviewed journals where science communication researchers publish. Underlying our research is a desire to give those interested in basic-science-related communication the ability to speak both quantitatively and qualitatively to the degree to which a 'basic science communication research literature' exists within core science communication journals.

The logic underlying the focus on these four journals is that we would expect that any sustained effort to study key challenges associated with communication in the context of basic science would appear—at least partly—in these journals. These journals are also key sites for research and discussion around communication-related topics such as "public engagement."[1] A separate research project by researchers at the University of Wisconsin—Madison simultaneously sought to characterize the broader landscape for science communication research beyond these four journals and additional short reports have been developed to focus on research in selected basic science areas (e.g., astronomy/ astrophysics/space neuroscience, etc.). The competing hypotheses underlying this research are that:

(a) a substantive basic science communication literature exists but that it needs to be foregrounded and mechanisms need to be found to tie disparate pieces together, or

(b) that no sustained literature exists.

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[1] For example, a keyword search on Web of Science for "public engagement" and "science" in June 2021 showed that these four journals are four of the top five journals where such content appears. PLOS ONE was the fourth most frequent user of the combined terms but was excluded here because it lacks specific focus on science communication topics.

If option ‘a’ is supported by the evidence then the challenge for the basic science community would be about how to better coordinate disparate lines of research. If option ‘b’ is supported, there may be an opportunity to build out a research program that meets the needs of practitioners while providing novel empirical questions for communication researchers. In exploring such questions, the research should also allow for a discussion of the degree to which the current focus of science communication research is too heavily weighted towards questions related to applied science.

By basic science we simply mean research undertaken without an immediate focus on a specific application, including the development of specific technologies. This might be similarly called curiosity driven or fundamental research. Example fields where basic science appears to be common include neuroscience, astrophysics/astronomy, particle physics, chemistry, evolutionary biology, and many others. In contrast, applied science topics might include areas where there is a desire to develop technologies or other tools to solve pressing social problems such as pollution, disease, or other threats to well-being. We similarly focus broadly on communication research “related to” basic science rather than research on “basic science communication.” We do this to reflect the reality that communication research may often focus on outcomes such as self-efficacy beliefs, trustworthiness beliefs, or risk/benefit beliefs related to a basic science topic. In such cases, the research ‘is related’ to basic science even though it is not specifically about the communication of specific scientific research results. We similarly understand ‘science communication’ research broadly to include any communication research ‘related to’ the natural and social sciences and scientists, not just the communication of scientific research.

Nothing in the current research, however, should be taken to mean that science communicators working along the continuum from basic to applied science should ignore evidence about how to communicate effectively … wherever they can get it. A further companion essay to this research summary argues that one way to reframe the challenge of identifying communication research relevant to communicating basic science is to identify the specific behavior-like goals (Besley et al., 2020) that people in basic science areas want to achieve from the efforts and other resources they put into communication.

In this regard, the expectation is that identifying the specific behaviors that we want to affect through communication can enable strategic communicators to look across the social sciences for evidence about what potential communication objectives might drive the desired behaviors (Besley et al., 2018) as well as tactics that might affect those objectives (Besley et al., 2019). Objectives, in this regard, can include scientific knowledge as well as a variety of evaluative beliefs (e.g., trustworthiness beliefs, risk/benefit beliefs, self-efficacy beliefs, etc.), feelings (e.g., interest, joy, disgust, anger, etc.), and framing of topics (e.g., Is this a health issue or an environmental issue?). Further, it should also be recognized that the goal behaviors and objectives that communicators can seek to change should typically include some of their own behaviors, knowledge, beliefs, feelings, and frames An ethical science communicator, in this regard, should always be eager to consider outside perspectives that might change how they think and feel about their research questions and methods.

The idea that ethical communicators need to make choices that allow them to update what they believe and feel about research-related topics, as well as how they frame such topics, reflects one way to think about the idea of meaningful, two-way 'public engagement.' Public engagement is also addressed in the current research summary inasmuch as the final step in the project provides a qualitative discussion of the degree to which the available literature emphasizes communicating in ways that allow people (including science communicators) to cognitive and emotionally engage in ways that foster the construction of stable evaluative beliefs, feelings, and frames. From this perspective, science communication that primarily focuses on approaches such as using heuristic cues to promote outcomes such as short-term behavior change are inconsistent with a desire for meaningful 'engagement' of science communicators and those with whom they communicate.

This Project

The project proceeded through four stages that we describe in turn. These included an initial generation of keywords that we hoped might help identify research papers focused on basic science (vs. applied science). For step 2, we used human coders to verify that the articles identified were at least somewhat substantively focused on a basic science topic. For step 3, we again used human coders to identify the type of data (if any) included in the paper. For step 4, we provide a qualitative description of the degree to which could provide evidence to help science communicators make evidence-based communication choices. In doing so, we also attempt to understand the degree to which there appears to be consistent overlapping themes and dialogue between the articles

Step 1: Keyword search

Our research team started the project by using Web of Science to download the titles, abstracts, and keywords (when available) for "articles" that appeared in *Public Understanding of Science*, *Science Communication*, the *Journal of Science Communication*, and the *International Journal of Science Education, Part B: Communication and Public Engagement* from their respective startups until December 31, 2020. We excluded content that Web of Science labeled as non-articles, including content labeled "book review[s]," "editorial material," and "proceedings paper[s]." After downloading, we uploaded the content to the textual analysis software NVivo and generated a list of the most commonly used substantive words. The team and other collaborators used judgement to identify words that seemed likely to help capture either applied or basic research topics. We also consulted the websites of the Kavli Foundation and the Department of Energy's Office of Science, given their focus on basic science, to ensure keywords related to funder priorities were included.

We provide the final list of keywords that we determined might be especially likely to indicate a potential focus on basic science in the first data column of table 1. As can be seen, of the 2,386 article abstracts/titles we searched, these keywords appeared in 237 articles (i.e., about 10%). Table 2 provides additional words we decided likely indicated a focus on applied research questions (e.g., how to get people to take action on climate change or consider buying genetically modified food). These are much more common. It should be noted, in this regard, that an article could include both basic and applied keywords and would still appear in the list of 237 articles designated as potentially including an emphasis on one or more basic science topics. Articles that included no keywords were also examined to ensure that important keywords related to basic science were not being missed. Many of these articles were about science, in general, rather than any specific topic (e.g., studies related to the Nobel prizes or overall attitudes about science). It should also be noted that the terms "basic science," "fundamental science," and "discovery science" generated no meaningful hits.

The most common types of 'basic science' keywords were related to astrophysics and astronomy, evolution, and nanoscience/nanotechnology. The "nanotech+" stem was the most common individual term. We debated, however, whether to consider this term an applied-science topic inasmuch as the focus of these articles is, almost by definition, applications of nanoscience (especially perceptions of risk related to nanoscience). We ultimately decided to retain nanotechnology content given the challenge of differentiating it from a focus on nanoscience and these represent about a third (32%) of all initially selected articles.

Step 2. Human Coding to Determine Eligibility

Next, as can also be seen in the second data row of table 1, the first author developed a coding scheme that was then trialed by the additional authors. This simple scheme was aimed at assessing whether the keyword-selected-articles had a substantive focus on a basic-science related topic. After training and refinement using an initial subset of the data, two coders were able to reliably code the content. They then coded the remaining content without knowing what content was being double-coded (Cronbach's Alpha coefficient for chance adjusted intercoder reliability = .81, n = 24). Disagreements were determined by discussion.

Textbox 1. Coding for Topical Inclusion

Yes/No: Is the article about an identifiable basic science field or fields?

1. Exclude if the article simply mentions a person in that field (e.g., an astronomer or neuroscientist) but is not focused on that field.
2. Exclude if the article appears only tangentially about the field (e.g., it mentions a field as an example but does not specifically focus on that field such as in the case of a study science fiction that mentions a field, but where the study is about fiction, or where the study is a content analysis where a basic science field is mentioned, but where the basic science field is not a specific focus).
3. Do NOT exclude if the article addresses a basic science topic/subject, as well as other non-basic topics such as if a study were to look at nanoscience [a basic science field] and genetic engineering [an applied topic], for example.

The result of step 2 was to bring the number of retained articles to 161, a reduction of 76 articles (and about 7% of the total content). As can be seen in table 2, much of this reduction occurred for articles focused on evolution and physics as several articles used these terms as part of a list of science topics that were not substantially discussed in the actual article. With regard to evolution, many of the exclusions were because the abstract talked about something like "the evolution of" a field. We did not, however, exclude articles focused on topics such as public opinion about evolution even though it could be argued that such articles are not actually focused on the substance of contemporary basic science debates (i.e., they are often really about education in a specific topic area). On the other hand, it seems possible that basic scientists involved in evolution-related research might want to focus their communication efforts in this area and thus we made the decision to retain these articles.

Step 3. Human Coding to Determine Data Type

The third step of our research involved downloading the full text of all 161 retained articles and attempting to determine the type of evidence (or other type of content) that they contained. In doing so, the goal was to identify a subset of articles that contained data that science communication practitioners focused on basic science might use to make evidence-based decisions about how to communicate. We were thus especially interested in identifying quantitative or qualitative data collected to assess research questions or hypotheses about how specific communication choices might affect specific communication outcomes, whether near term objectives or long-term goals (Bennett et al., 2019), as described above. We used the same training and coding strategy used in step 1 but with multiple coding decisions. Again, after training, we were able to obtain acceptable levels of intercoder reliability for the most commonly occurring types of articles post-training (i.e., coders did not know what articles were being double-coded; see table 2 for reliability coefficients).

As table 2 shows, what we found is that slightly more than 1 in 4 of the 161 retained articles provided quantitative evidence from surveys or experiments, whereas slightly less than 1 in 4 provided qualitative evidence from interviews or questionnaires. About a 1 in 5 were content analyses and just more than a 1 in 10 were case studies. The remaining were theoretical or historical discussions.

Textbox 2: Coding for Content Type.

Yes/No: Does the article provide systematic and/or substantive new <u>quantitative</u> evidence from surveys or quantitative experiment? Analyses could include testing of differences between groups using something like chi-square tests or other non-parametric, ANOVA or t-tests, or linear modeling (e.g., correlation, regression). Simple descriptive statistics are not likely adequate. If the evidence is coded from open-ended responses, the focus should be on a quantification of the prevalence of a specific response using a meaningful sample of a specific population; this will typically mean samples above n = 100 and some check of intercoder reliability or coded using automated/algorithmic coding).

Yes/No: Did the article provide systematic and/or substantive <u>qualitative evidence</u> of the results of interviews, surveys or direct observation (i.e., not media content) of contemporaneous events?* In such cases, there is likely to be detailed thematic coding and the sample will typically be a small (n < 50) convenience/theoretical sample and there will be no quantitative intercoder reliability (i.e. Krippendorff's alpha or Cohen's Kappa). Numbers may be provided but these will be likely be used only descriptively). Do not include articles where there may be quotations from interviews or questionnaires but no discussion of systematic analysis.

Yes/No: Does the article provide systematic and/or substantive new evidence from a content analysis of *contemporaneous** news content or other type of publicly available content (e.g., movies, online videos, social media posts, etc.).

Yes/No: Does the article provide a systematic and/or substantive historical analysis of content? The focus should be on a specific set of years that was selected based on specific interest in those years, not because they were the years that most readily available.

Yes/No: Does the article provide a case summary of a recent activity without substantive quantitative data analysis (but not interviews or systematic observation)? This might involve quotations that are not described in a way that suggests they were analyzed systematically.

Yes/No: Does the article focus on providing a theoretical/conceptual/philosophical arguments, including theoretical/conceptual/philosophical critiques of past empirical research without new data?

* Systematic and substantive likely means a discussion of methods/methodological choices as well meaningful reporting of results. Contemporaneous refers to data that is from the specific time period (e.g., last 5-10 years) in which the research was collected and seeks to speak to a still-current issue whereas non-contemporaneous would speak to previous decades/historical era/events.

Step 4. Qualitative Assessment of Articles with Quantitative, Qualitative, and Case Study Data

The final step involved the first author using NVivo software to thematically code the 100 abstracts from articles that step three indicated included quantitative, qualitative, and case study data (note that five articles were coded as including both quantitative and qualitative data). We did so to try to assess if articles were speaking to each other in high-level ways. We did not do a formal cross citation analysis or review of full articles at this stage because our expectation was that we would be able to make a reasonable assessment of the corpus using a less resource intensive approach.

Given the small number of data-driven articles (less than 5% of all articles), it should not be surprising that we saw no clear, sustained focus in the abstracts. In other words, in most cases, it did not appear that the available studies built on each other or sought to answer similar questions in a way that would allow for the accumulation of focused insight.

The most common outcome (or potential outcome) that abstracts seemed to speak to was science knowledge (about 4 in 10 of the articles) and the second most common potential outcome was risk/benefit beliefs (about 3 in 10 of the articles). In some cases, the emphasis was on how events (including discussion-focused events), exhibits, or in-school activities might foster increases in science knowledge or risk- and benefit-related beliefs. In other cases, these variables were included in surveys and the research focused on the correlations between these variables potential communication goals such as public acceptance or support for a science-related policy. Much of this survey research was done in the context of nanotechnology. The only other potential communication outcomes mentioned in more than 1 in 10 articles was some form of emotion (including interest or ‘motivation’). Other potential communication outcomes such as audience self-efficacy, beliefs about scientists (i.e., trustworthiness beliefs), and the (re)framing of scientific issues were mentioned only rarely.

Beyond immediate potential outcomes of communication, the only longer-term goal that appeared in the data-driven abstracts reviewed was support (including support for funding) or acceptance for science or a specific technology (e.g., nanotechnology). This type of goal was noted by about 1 in 10 of the 100 abstracts reviewed in step 4. The goal of encouraging young people to consider scientific careers was the next most common and appeared in slightly less than 1 in 10 of the articles. In terms of communication tactics, about 3 in 10 of the articles analyzed seemed to focus on some sort of event or exhibit while about 1 in 10 focused on media content and 1 in 10 focused on the impact of images or art-related activities. It is also noteworthy that about 1 in 10 of the articles focused on the views of scientists using either surveys or interviews. These often seemed to focus on views about how and when to communicate.

Perhaps most importantly, our overall sense in reviewing the basic science-related articles that we identified in step 3 is that there did not appear to be any clear effort by the research to grapple with basic science as a stand-alone concept. More typically, the basic science topic or field was simply (1) a backdrop for an effort to study whether there was a relationship between a communication activity (i.e., tactic) and an outcome (especially learning), or (2) reframed in terms of potential future application. Finding an applied angle of basic science topics was especially common in the context of nanotechnology where issues of perceived risks and benefits were frequently discussed in the context of future consumer acceptance. It also, however, occurred in the context of neuroscience where there was an emphasis on how audiences perceive neuroscience imagery as a function of mental health/learning, and in the case of evolution where the focus was often related to education issues.

Further, in reading the abstracts (and many of the full articles), we developed the sense that, for example, neuroscience articles largely sought to speak to people already interested in neuroscience whereas astronomy focused articles sought to speak to those already interested in astronomy. This is a potential topic for more formal review of citation patterns, but our expectation is that such an effort would only quantify what our initial reading seems to show.

Discussion

We came away from our review of the selected research with the sense that no sustained literature on communication related to basic science exists within core science communication journals. In this regard, only a small fraction (less than 10%) of the articles in *Public Understanding of Science*, *Science Communication*, the *Journal of Science Communication*, and the *International Journal of Science Education, Part B: Communication and Public Engagement* seem to have any meaningful focus on basic science. Further, the basic-science-related articles that do exist seem to focus largely on science learning (i.e., comprehension or understanding) and risk/benefit beliefs with little broader connection to why learning or risk/benefit beliefs might be important towards achieving larger goals related to basic science. This means, for example, there was little basic-science-related research on the relationship between shorter term outcomes such as learning and longer-term outcomes that we might want to see as a result of learning (or risk/benefit beliefs, or other potential communication outcomes). The focus on learning and risks and benefits also means there was very limited research on the broader range of potential outcomes that communicators could potentially affect through communication (e.g., changes in self-efficacy, risk/benefit beliefs, trust-related beliefs, identity beliefs, framing, emotions, etc.). There was similarly almost no focus on changes in science communicators' beliefs, feelings, frames, or behaviors.

Two additional limitations we see in the analyzed literature is that (1) much of the research seemed to focus on the particulars of the topic rather than seeking to provide generalizable information about how specific communication choices (e.g., how to set up an event or produce a document) might contribute to specific communication outcomes across basic science contexts, and (2) the particular challenges of communicating in the context of basic science was rarely the focus of attention. On this latter point, although the article topics were sometimes basic-science related, the actual research often seemed to emphasize applied questions such as whether the application of the science might lead to risks or benefits to citizens. This was especially the case in research related to nanotechnology, neuroscience, and evolution. This approach may have made sense for the specific studies—and this is not a critique of such work—but one consequence of such approaches is that the overall community may be missing opportunities to develop evidence-based guidance.

A final potential limitation we noted was that the available research tended to focus on 'engagement' only in a generic sense. With a few notable exceptions (e.g., Tingay, 2018), there was little sense that the focus in the analyzed literature was specifically on using tools such as dialogue to encourage communication participants (including scientists or other science communicators) to slow down and think deeply (i.e., cognitively engage) in ways that might lead to the development of long-term evaluative beliefs.

As discussed in a companion essay, one path forward for those committed to expanding communication research related to basic science might be to identify specific long-term goals that are priorities for communicators working in the basic sciences. These might include goals such as ensuring funding support for scientific research and education, identifying key issues for further research, promoting consideration of scientific careers, or even simply ensuring strong relationships between scientific communities and the broader communities in which we all live. The expectation is that prioritizing specific long-term goals would allow researchers and practitioners to collectively think through the shorter-term outcomes (e.g., trust building, reframing, self-efficacy development, etc.) that theory and experience suggest might contribute to achieving those goals. They could then prioritize research aimed at identifying communication activities (i.e., tactics) that might lead to the shorter-term outcomes that enable goal achievement. These might include specific messages or content, ways of structuring events, effective styles, and specific channels or communicator characteristics that work especially well.

A further benefit of starting with goal identification is that it could enable research that spans across topics. In this regard, one might ask whether the factors that lead to support for funding in one area (e.g., astronomy) are similar to the factors that lead to support for alternative areas (e.g., any other basic or applied topic); or whether the factors that lead young people to consider scientific careers vary by topic. It might be that some issues come with specific affordances that make them especially effective for achieving some goals. For example, there appears to be a tendency within astronomy focused communication to suggest that the nature of astronomy lends itself to communication aimed at evoking emotions such as wonder or awe while also enabling the development of self-efficacy through the process of systematic observation. It might be that such features lend itself to science recruitment type goals for some types of young people. For other goals, other issues might have advantageous characteristics.

Table 1. Number of articles with keywords or coded content in articles from (N = 2,365) from *Public Understanding of Science* (n = 1,061), *Science Communication* (n = 612), *Journal of Science Communication* (n = 513), and *International Journal of Science Education Part B: Communication and Public Engagemen*t (n = 179), with n = 41 removed due to lack of abstract data/cleaning*

	Step 1: Keyword queries (N = 2,386)	Step 2: Human Coding to Confirm Relevance*	Step 3: Coding of Relevant Retained Articles to Determine the Type of Data Included in the Article (n = 161)**					
	Articles Returned	Article Retained (a = .81, N = 2,386)	Quantitative (a = .95)	Qualitative (a = .79)	Content Analysis (a = .81)	Theoretical (a = .65)	Case Study (a = .85)	Historical (a = .NA)
Astron+	28	25	7	5	6	2	5	1
Cosmol+	2	2	0	0	1	0	1	0
Galaxy	1	1	1	0	0	0	0	0
Neutrino	1	1	0	0	1	0	0	0
Particle	2	2	1	0	0	1	0	0
Planet+	9	6	1	1	2	0	2	0
Quark	2	1	0	0	0	0	1	0
Solar system	1	1	0	1	0	0	0	0
Astrophy+	2	2	2	1	0	0	0	0
Chemi+	22	14	5	4	5	2	1	0
Evolution+	60	29	4	2	9	10	2	2
Nanosci+	7	7	2	2	1	2	2	0
Nanotech+	63	60	22	16	11	9	7	0
Neuro+	22	15	2	4	4	2	2	1
Physics	45	24	7	6	3	4	5	3
True Total***	237	161	47	37	35	26	21	6
Percentage	10%	7%	29%	23%	22%	16%	13%	4%

Notes *Downloaded from Web of Science, ** Cronbach's alpha for intercoder reliability with two coders (Step 2: n = 24, ~15% of step 1 articles; Step 3: ~30% of Step 2 articles). ***Given that many articles were coded to more than one keyword, the true total is the total number of unique articles.

Table 2. Number of articles with ‘applied science’ keywords from (N = 2,386) from *Public Understanding of Science* (n = 1,061), *Science Communication* (n = 629), *Journal of Science Communication* (n = 513), and *International Journal of Science Education Part B: Communication and Public Engagemen*t (n = 183)*

Keyword	#	Keyword	#	Keyword	#	Keyword	#	Keyword	#
Technology	650	Threat+	63	Therap+	22	Renewable	9	Carbon dioxide	3
Polic+	318	Religio+	61	Species	22	Flu	7	Recycling	3
Education+	313	National Science	59	Philosoph+	21	Physician	7	Wind	3
Risk+	271	Career	52	Synthetic	20	Curiosity	7	Car	3
Fund	265	Agricul+	48	Zoo+	19	Invasive	7	Turbine	2
Politic+	246	Sustainab+	43	Diagnos+	18	Artificial intelligence	7	Agron+	1
Govern+	243	Ecology	42	Mobile	18	Vehicle	7	Astrol+	1
Health+	233	Math+	41	Embryo+	17	Autism	6	Computer Scientists	1
Genetic+	215	Energy	41	Virus	17	Ebola	6	Aquatic	1
Climate	198	Psychology	38	Doctor	16	Chemistry	6	Carbon capture	1
Environmental+	197	Global warming	38	Genetically engineered	16	Hydraulic fracturing	6	Crispr	1
Histor+	138	GM	35	Cancer	15	H1N1+	5	Battery	1
Medic+	121	Biomed+	35	Clinic+	15	Pharma+	5	Solar Panel	1
Food+	97	Animal+	35	Law	14	Cognitive science	5	Translational	0
Museum	93	Nuclear	31	Weather+	14	Geoeng+	5	Aerosp+	0
Accept+	90	Conservation	29	Corona+	12	SARS	4	Astrob+	0
Biotech+	86	Vaccin+	28	Autonomous	11	Biosci+	4	Atomic	0
Engineer+	83	STEM Cell	27	Drug	10	Geolog+	4	Dam	0
Genetically modified	75	Earth+	26	Chemic+	10	Endangered	4	Hydropower	0
Regulat+	72	Patient	25	GMO+	9	Storage	4	Solar cell	0
Industry	71	Epistemolog+	24	Botan+	9	Hydrogen	4	Automobile	0
Disease	69	Clone	24	Fracking	9	Social Psychology	3	Drone	0
Biolog+	66								

Notes: # refers to the number of articles retrieved using the keyword from the title or abstract downloaded from Web of Science up to December 31, 2020.

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