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SCIENCE-EDU-COMMUNICATION: TRENDS REVEAL IN 20 YEARS OF SCIENCE COMMUNICATION RESEARCH

Leon Yufeng Wu,
Nathan M. Truong,
Hsin-Yen Lu,
Yuen-Hsien Tseng,
Chun-Yen Chang

Abstract. *By investigating scholarly output in science communication from 1997 to 2018, this research sought evidence that science education has been increasingly focusing on communication methods to reach the public. Through an automatic scientometric method, this study analyzed 1300 articles published in two leading journals in the field of science communication. As a result, seven trends were revealed and categorized into three themes: Public engagement with science (PES); Media and science (MS); and Issues in science (IS). Furthermore, PES and MS scholarly output were found increased significantly. The findings confirmed the goal of this research. However, it then suggested a research area of bridging science education and science communication that is currently less explored. Given increased focus towards PES and MS, these fields are primed for further collaboration to more engage the public in science learning.*

Keywords: *CATAR, scientometric analysis, science communication, science education, science-edu-communication.*

Leon Yufeng Wu
Chung Yuan Christian University, Taiwan
Nathan M. Truong, Hsin-Yen Lu, Yuen-Hsien Tseng, Chun-Yen Chang
National Taiwan Normal University, Taiwan

Introduction

"Science is an integrative force and Science Education can help to understand the changing world" (Lakhvich, 2010, p. 164). However, understanding the world has become ever more challenging for citizens than it has been in the past, because people have been inundated with incomplete and erroneous information from the media (L. Y. Wu et al., 2015). If the media at a certain level represents the "skin of culture" (Kerckhove, 1995), and science content in the media has not been communicated well to the public, then the goal of science education to help promote understanding of the changing world is hindered. A gap was found between the role for science education in communicating science to the public (Lewenstein, 2015), and the goal of public understanding of science (Bauer, Allum, & Miller, 2007; Martin, 2017).

Science education as a research field, is a field in which research trends have been both qualitatively and quantitatively analyzed, thus providing the research community with nuanced data of the field's goals and directions (Cavas, Cavas, Ozdem, Rannikmae, & Ertepinar, 2012; T.-C. Lin, Lin, & Tsai, 2014; Tsai & Wen, 2005). Teaching and learning in science, along with topics of interest and trends in science education have been documented and conveyed trends over the past decades towards topics of context of student learning and conceptual change (Chang, Chang, & Tseng, 2010; Lee, Wu, & Tsai, 2009; Tsai & Wen, 2005). One such trend was the increasing international collaborative science education research, as indicated by the increased output from non-English-speaking countries over the last decade (Tsai & Wen, 2005).

Science communication, on the other hand, has engaged with the concepts of scientific literacy or understanding, public understanding of science, and science and its relationship with society, shifting from a deficit oriented model to a more interactive process of engagement, since the 1960's (Bauer et al., 2007; Bucchi & Trench, 2008). Diverse in its research fields, science communication encompasses media, communication techniques, and the process of relaying science to groups that interpret new information and science in

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a variety of ways. It has grown to encompass research that overlaps with fields such as nutrition and environment, but continues to lack robust communication between researchers within the various fields concerning science communication (Logan, 2001).

While collaboration between the fields of science education and science communication is largely absent and their research mainly distinct in development, the two fields are largely aligned in their objectives and complementary in their methods (Baram-Tsabari & Osborne, 2015). Both fields wish to develop increased broad scientific literacy and competency in critical thinking and analysis so that individuals can publicly engage in the discussion of science and its effects on society (Feinstein, 2015). Science education and communication are alike in substance but differ in style and setting. Science communication focuses on broad public education while science education communicates science on a more intimate level in classrooms and through teachers; both fields are distinct in their research practices and collaborations, even though formalized disciplinary boundaries do not prevent the fields from crossing (Davis & Russ, 2015; Lewenstein, 2015). Despite sharing so much of the same-spirited ideas, both fields actually do not contribute to each other's research in a continuously collaborative manner as their overlapping goals would suggest. Thus, there is a risk in conducting research that has already been addressed in the respective fields of science communication or education (Baram-Tsabari & Osborne, 2015; Lewenstein, 2015).

In seeking to educate the public through science communication, there has been a growing shift from a deficit-oriented model towards one that stresses scientific discussion and conversation with the public (Bucchi, 2008; McNeil, 2013). The deficit-oriented model broadly views the scientific community as an expert entity that educates the public through gradual dispersion of information through media and communication outlets. Though experts are the main communicators, the act of communication with non-experts will result in changes to the original science content and message (Claessens, 2008; Hilgartner, 1990; McNeil, 2013; Sturgis & Allum, 2004; Suldovsky, 2016). Science communication, in tension with the deficit-oriented model, has in recent years shifted towards a model that regards the public as an interactive partner in discussion in science-related issues (Baram-Tsabari & Osborne, 2015; Bucchi, 2013). This shift, in many ways, is congruent with science education's emphasis on activity-based learning and active discussion in science classrooms, a major theme that will guide research in communication and education for years to come (Baram-Tsabari & Osborne, 2015). The emphasis on a more collaborative science communication model emphasizing conversation between scientists and the public promises to expand the diversity of stakeholders involved in developing science communication. While this shift in science communication model focus is present, the deficit model will still play a significant role because the public will still need to rely on information derived from scientific experts and interactive modes of communication also serve to further enrich the information science communicators convey (Hilgartner, 1990).

Since science communication not only involves accurately communicating science concepts with precision, but also appealing to peoples' values and the "entertainment" component of peoples' reception, the media is a distinctive component of science communication and often times the bridge through which the scientific community communicates (Friedman, Dunwoody, & Rogers, 1999). Media can have a negative role in terms of educating the public as studies have shown that the manner in which media communicates science affects the cognitive acquisition of scientific concepts (Berinstein, 2006). The ongoing conversation about the purpose of science communication might tap into the goals of science in the public sphere and beg the question as to how effectively and in what modality science literacy may be achieved (Bauer et al., 2007).

While the direction of science communication research is unclear in literature and form, the trend studies carried out in science education give form to how this closely related field has developed over time (Chang et al., 2010; T.-C. Lin et al., 2014; Tsai & Wen, 2005). These studies have been carried out in a systematic sense categorizing research under predetermined categories, as well as through automated computer algorithms that cluster research through citation-linked coupling. The findings of these studies have informed researchers of the trends in science education, revealing patterns that otherwise would not be available unless through large manual analysis. These broad analyses also allow scholars new to a field to access the large trends of a given field and target research in conjunction with a significant topic (Cavas et al., 2012).

Purpose and Research Questions

By investigating scholarly output in science communication from 1997 to 2018, this research sought evidence that science education has been increasingly focusing on communication methods to reach the public. Instead of looking at research trends in science education, this research proposed a trend analysis in science communication

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over the previous 21 years, with the goal of revealing prominent trends in science communication to allow coupling of these findings with other research fields, particularly science education. This analysis sought to elucidate the emerging trend in which the goals of science education and communication research were shared, offering fresh insights into the shifts of science communication as well as future areas of collaboration between two fields that historically have not interacted but could stand to benefit in doing so (Baram-Tsabari & Osborne, 2015; Lewenstein, 2015; Ogawa, 2011; L. Y. Wu et al., 2015).

The research's aim was to provide and clarify areas of potential further research in conjunction with fields related to science education and science communication and provide a foundation for future research areas and trends. Research questions to be answered were as follows:

1. What are the major research trends in the field of science communication?
2. How does science education play a role in the research trends of science communication?

Research Methodology

Analysis Tool Selection

Traditionally, trends analysis studies have sought to take large amounts of research papers and sort them into pre-determined categories based on arbitrary or previously utilized standards (Lee et al., 2009; Tsai & Wen, 2005). Since this research analyzed papers from a 21-year period, it was determined an automatic content analysis method would serve as the most efficient and detailed method to evaluate the large quantity of research articles while minimizing human error. Science education and tourism studies have made use of Content Analysis Toolkit for Academic Research (CATAR) developed by Tseng (2018) to conduct bibliographic analysis.

CATAR's use of multi-stage clustering and generic title labeling proves most useful to grouping papers into broad categories and facilitating labeling (Tseng, 2010; Tseng & Tsay, 2013). This method also serves to minimize influence of researchers' personal interests and professional knowledge in reviewing literature. It has been previously used to obtain an overview of reoccurring research topics and track their trends over time and their relationships to countries and institutions (Chang et al., 2010; Yuan, Gretzel, & Tseng, 2015). This information can then be used to suggest further areas of study as well as give quantitative evidence in describing a field and its directions, information, especially relevant to those unfamiliar with a field such as new students and researchers.

CATAR makes use of bibliographic coupling as a fundamental tool in grouping papers, and thus using Social Sciences Citation Index journals was fitting for CATAR; papers with shared citations are clustered together and can be assumed to have similar focuses. CATAR makes use of this idea through grouping papers with similar citations in stages to provide specific categories for research analysis as well as more broad categories. CATAR is currently limited to using World of Science (WoS) article data and data converted into the WoS formats. CATAR, while useful to compile large amounts of data, also requires the user to select the quantity of coupling iterations used on selected data, which is four in this research. More detailed explanations of CATAR can be found in the research of Tseng and Tsay (2013).

The following steps provide a summary of the six main steps of CATAR to assist in understanding the results that follow.

Step 1: Text Segmentation

Each record from the Thomson's Web of Science contains about 40 fields of information ranging from paper title, authors, publication years and journal title, etc. This step chooses the relevant pieces of data for analysis. We identify at least seven of them for use in analysis. Below are their abbreviations, definitions, and examples:

AU: Authors, e.g., Harambam, J Aupers, S.

TI: Publication title, e.g. Contesting epistemic authority: Conspiracy theories on the boundaries of science.

SO: Journal title, e.g., *Public Understanding of Science*.

AB: Publication's abstract.

C1: First author's country, extracted from first author's research institution.

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CR: Normalized citations, e.g. Campbell Colin, 1972; *Sociological YB Reli*, V5, P119.

PY: Year of publication, e.g. 2015.

Step 2: Similarity Computation

After CATAR captures each article's relevant information, the program used the common citations normalized by each paper's individual citations to calculate the similarities between other articles. The more of the same articles each paper cites, the more likely the articles are discussing the same topic. This is the foundation of *bibliographic coupling* that creates clusters of research topics.

Step 3: Multi-Stage Clustering (MSC)

A clustering algorithm called *complete linkage clustering* is used to discern the underlying themes of the collection of papers and assign the journals to individual clusters (Salton, 1989). CATAR first recognizes each article as a single cluster and then groups the most similar pairs of clusters into a larger cluster and repeats this rule until a reasonable and manageable number of clusters are formed or can no longer be merged. For example, three rounds could yield 35 clusters, whereas four rounds of clustering can yield nine clusters. There is a determined similarity threshold for clusters to be grouped together, where pairs of clusters with a similarity larger than the determined threshold are grouped and those not fulfilling the threshold are excluded, resulting in a smaller set of resulting papers. This research utilized a similarity threshold of .05 and four rounds of clustering were carried out to provide the final research topics.

Step 4: Cluster Labeling

While CATAR is an automated process, largely taking care of the intensive labor of analyzing large amounts of research articles with human interpretation, analysts still need to read through titles and abstracts to determine the broad topics covered by each cluster. CATAR uses a text mining approach to generate automatic descriptions for each cluster. The algorithm filters through words in the titles and abstracts of each paper and extracts the most repeated words and phrases and uses the five most correlated terms to serve as the descriptors for each cluster. These words provide a basis for researchers to characterize clusters with relevant descriptors to label a research topic.

Step 5: Facet Analysis

Once the topics have been detected in cluster labelling, it becomes more possible to analyze multiple facets of information from each article over a larger set of data. For example, one can know the topic distributions of all the authors, elucidating their areas of expertise in addition to their individual productivity. One can also analyze yearly distributions of each topic allowing for topic trends to emerge more clearly. The topic trends can also be quantified, such as when determining the slope of a linear regression line that best fits the time series. These analyses are the major focus of this research and allow for broad level systematic analysis of large sets of data.

Step 6: Visualization

The last step was to visually represent the clusters using Multi-Stage Clustering (MSC) and Multi-Dimensional Scaling (MDS). Using the pre-calculated similarities between topics, the MSC organizes the topics to display a structure that readily shows information about each cluster (like descriptors). The MDS technique also computes a location for each cluster in Euclidean space to aid in visual interpretation. A topic map is then created where factors such as cluster size, closeness, and spatial topic distribution are readily interpreted. The representations provide different ways to explore and interpret the data. The two-dimensional visualization helps understand inter-cluster relationships by distance and orientation.

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Journal Selection

To understand how science communication has developed since 1997, researchers must explore the large trends of the field and the development of academic discourse, especially in conjunction with other relevant major themes. In carrying out a trends study, factors such as related fields and topics also can provide useful information in evaluating science communication's influence or relationship to other research areas. Prior to this research, there has been no significant quantitative trends analysis of science communication research journals. Researchers had carried analysis studies in the related field of science education and others such as tourism and general education (Chang et al., 2010; Lee et al., 2009; Tsai & Wen, 2005; Tseng & Tsay, 2013; Yuan et al., 2015) but to date, science communication has been largely isolated in this course of research. To present a representative and longitudinal overview of science communication over the years, this research conducted trends analysis of science communication research pulling from 1300 articles dating from January 1, 1997 to June 23, 2018 in the journals, *Science Communication* and *Public Understanding of Science*. These years were chosen to encompass the earliest period of journal indexing (1997 for *Science Communication* and 1994 for *Public Understanding of Science)* to the most-recent complete year that research was available, maximizing the broadest quantity of data. These journals also have cross-disciplinary relevance, especially in the related topics of science education, thus providing a foundation to find linkages with the two fields. The study chose these two journals due to their high citation rates within the field of science communication. Additionally, their inclusion in the Social Sciences Citation Index of the Web of Science (WoS) ensures the documents can be analyzed using CATAR. Currently, CATAR can only analyze WoS database. Thus, data collection process excluded some other potential science communication related journals such as *International Journal of Science Education, Part B*, and *Journal of Science Communication*.

The data for the publications analysis were downloaded from Thomson Reuter's ISI Web of Science (WoS) during mid-June 2018 to ensure that completed research articles up until 2018 would be included in the database of articles. The type of the documents only included research articles, excluding commentaries, editorials, and short research reports or book reviews to provide the most direct source of research.

Justification for Validity

The data set consisted of 1300 papers (i.e., PUS: 819; SC: 481) and was narrowed down to 393 articles after the fourth clustering analysis (see Step 4 Cluster labelling) removed extraneous papers that were not categorized under a broader topic. It is common during outlier removal in the MSC process for a manageable number of research themes to analyze. A "long tail effect" (Figure.1) could explain why a large portion of the papers were removed in clustering analysis (Tseng, 2018).

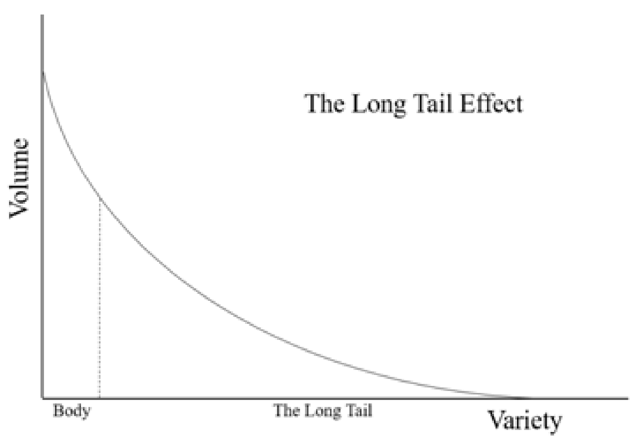

Figure 1. A demonstration of the Long Tail effect.

It is normal in clustering analysis because more than average of the papers usually deal with independent issues, which is similar to a phenomenon in business such as online book sales. More than 40% of sales are produced

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by a variety of customers' personal interests (Brynjolfsson, Hu, & Smith, 2003). Thus, 393 articles were analyzed in this broader trends study, excluding 907 of originally chosen papers, a reduction rate congruous with previous studies and additionally explained below (Chang et al., 2010). Moreover, for assuring the least potential bias while finalizing the research topics (see Step 3~5), two analysts with science communication domain knowledge read together through the titles and abstracts to generate the topics.

Research Results

Seven Topics Emerge in Science Communication Research

Seven categories of science communication research trends emerged from Science Communication (SC) and Public Understanding of Science (PUS) during the past two decades (i.e. 1997-2018). Figure 2 recorded the article counts and percentages in each of the seven categories.

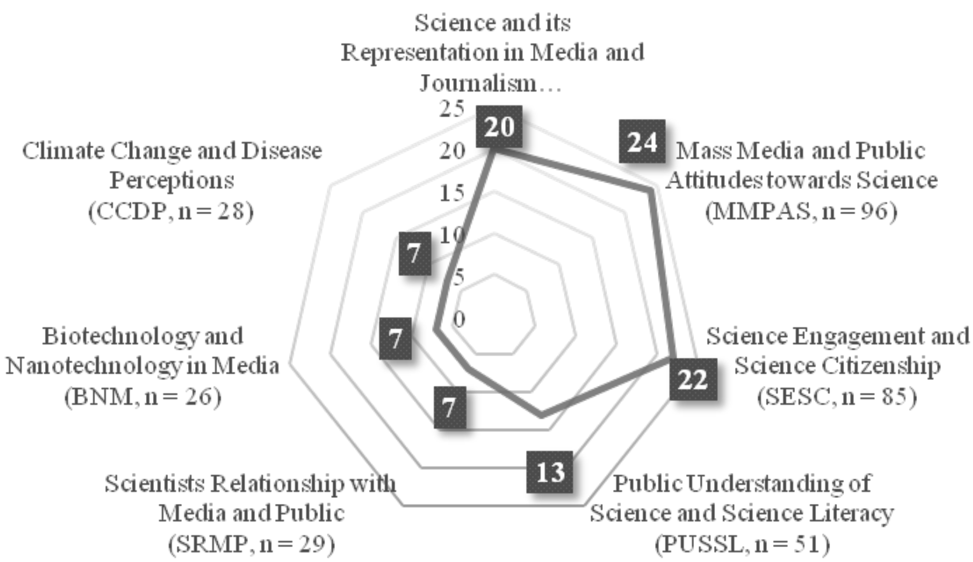

Figure 2. Seven topic categories in science communication research and their composition from journals of PUS and SC from 1997 to mid-2018 (n = 393).

The spatial relatedness among the seven topics are mapped in Figure 3, where a circle represents a topic and its size is proportional to the number of articles contained within the topic. The topic map was illustrated by using Perl programming language (Tseng & Tsay, 2013). Relatedness between circles were presented in terms of orientation and distance. The circles with overlap represent topics that have stronger relationships in terms of topic similarity and degree of citation linking. Circles that are located at farther distances from each other indicate topics that are mainly independent or largely not similar.

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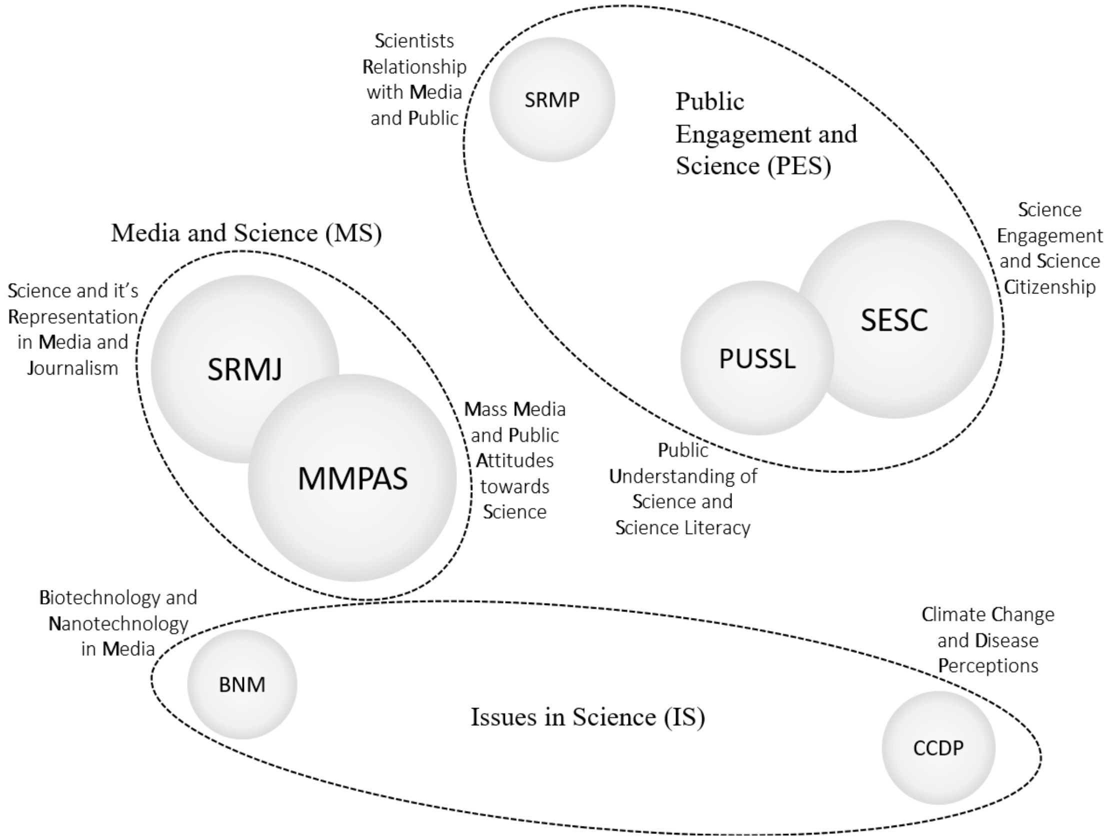

Figure 3. Topic map rendered by multi-dimensional scaling (MDS) for multi-stage clustering of *Science Communication* and *Public Understanding of Science* journal articles.

Table 1 shows detailed subtopics within the seven trends under the three themes.

Table 1. Topic themes encompassing the seven topics of science communication research and counts of articles in subtopics.

Themes	Abbreviations/Topics (Trends)	Docs	Subtopics (n)
Media and Science (MS)	SRMJ/Science and it's Representation in Media and Journalism	78	Science in the News (21) News Frames and Science (28) Media Representations (16) Media Coverage (13)
	MMPAS/Mass Media and Public Attitudes towards Science	96	Effects of Mass Media (49) Issue-related Coverage in Media (34) Risk and Uncertainty Perceptions (13)
Public Engagement and Science (PES)	SRMP/ Scientists Relationship with Media and Public	29	Scientists' Participation (17) Scientists for Public Engagement (12)
	SESC/ Science Engagement and Science Citizenship	85	Public Engagement with Science (24) Constructing Communication (32) Engagement Methodology (17) Trust, Identities and Risk (12)
	PUSSL/ Public Understanding of Science and Science Literacy	51	Public Participation (15) Attitudes toward Science (36)

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Themes	Abbreviations/Topics (Trends)	Docs	Subtopics (n)
Issues in Science (IS)	BNM/ Biotechnology and Nanotechnology in Media	26	Genetically Modified Food and Biotechnology (13) Public and Nanotechnology (13)
	CCDP/ Climate Change and Disease Perceptions	28	Climate Change and Global Warming (14) Climate Technology and Actions (14)

Figure 4 demonstrates the publication counts for development trends of the seven topics of science communication research from 1997-2018.

Figure 4. The publication counts for development trends of the seven topics of science communication research from 1997-2018.

Finally, Figure 5 merged the seven science communication research topics into three themes.

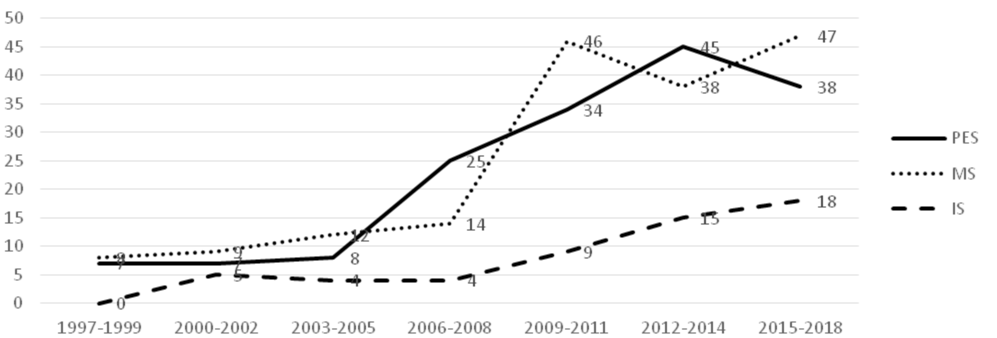

Figure 5. The publication counts for the development of overall trends for the seven science communication topics from 1997-2018.

Trends Concerning Theme PES

There was an increase in Theme PES research, encompassing topics: "Public Perception and Understanding of Science and Science Literacy (PUSSL)," "Science Engagement and Science Citizenship (SESC)," and "Scientists' Relationship with Media and Public (SRMP)" overall since 1997. SRMP has maintained steady output during the 21

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year period (Figure 4). SESC has experienced general increases in research output since 1997 with a decline since 2014 and PUSSL has lower overall output, but has increased in publications for the duration from 1997-2018 (Figure 4). SESC, of the three topics in this theme, has the highest overall output during this period, and is a focal point of the results given its high share of research output over the last decade.

Trends Concerning Theme MS

Overall, Media and Science as a theme has had overall increases in research output during the entire period of 1997-2018. Researches regarding "Science and its Representation in Media and Journalism (SRMJ)" remain constant in output except an uptick in output during the 2009-2011 period. The topic of "Mass Media and Public Attitudes Towards Science (MMPAS)" overall have increased, with sharp increases in output starting in 2006. The possible reasons for this are discussed in the next section. The topic of media and science is a commonly present topic in science communication and thus is reliably researched and consistently a topic of discussion. The trends of these topics may also coincide with other factors in research and science communication.

Trends Concerning Theme IS

Biotechnology and Nanatechnology in Media (BNM) and Climate Change and Disease Perception (CCDP) all covered material regarding prominent topics in science that are of particular interest to the public and remain present in contemporary media. Climate change, health, disease, and biotechnology among other topics have remained publicly prominent for some time. These topics are either seen as controversial, referencing aspects of science that many in the public may fear, may not adequately understand, or target topics that are of immediate relevance to individuals. BNM and CCDP have received increased publishing output most notably from 2006-2018 with a sharp uptick in publishing, though at a lower rate than those of Theme PES.

General Trends Across Three Themes

The trends across all topics were documented in Figure 4 and explained in following sections. CATAR automatic content analysis generated seven main topics and three overarching themes based on the similarities between topics as indicated by their proximity in the topic map or their relatedness as prominent topics in science. To encompass topics that largely engage in the interface between the public, science and scientists, Theme PES: Public Engagement and Science was formed. Theme MS: Media and Science, focuses on the portrayal and coverage of science in the media. Theme IS: Issues in Science covers topics that may not be directly related but nonetheless, share the common trait of being prominently featured in media and discussions of science.

Discussion

RQ1: What are the major research trends in the field of science communication?

While this research organizes overall trends of science communication, it also serves the purpose of providing a basis for linkages with other fields of research related to the analyzed research papers. This connection is especially relevant in fields that previously have collaborated the fields of interest discussed in this research as well as other fields where relationships may remain unexplored. This research discusses the linkages science communication has with previous trends studies in science education.

Theme MS: Increased Media Attention to Science

The increase in Media themed research is a primary finding of this research. Research relating to *Media and Science* showed a general upward trend of output over the last two decades, with the largest increase taking place after 2006. Media is a fundamental component of science communication in today's landscape given its role of interfacing with the public as well as the duty scientists feel to interact with the media (Peters, 2013). Research related to science's representation and framing in the media (MMPAS) have shown steady presence with an increased output in 2009-2011 (Figure 3), while research relating to mass media and public attitudes towards science

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have increased in output throughout 1997-2018. These topics of research are primarily concerned with how media frames or represents science and how that affects the ways science is perceived in the public. Given that media is a primary vehicle for communication, the upward trend in research indicates that during the past two decades, media has only grown in importance in science communication, especially given the role it plays in communicating and representing science (Nelkin, 1995). How science is presented and how the public feels about science are increasingly topics of interest and consequently form a large theme in science communication research. In addition, journals such as *Journal of Science & Popular Culture*, *Journal of Science Communication, International Journal of Science Education, Part B,* or other international journals provide further context to science in media

RQ2: How does science education play a role in the research trends of science communication?

Theme PES: Engaging in a Conversation with Science

One main trend exists in Theme PES: Public Engagement with Science. Over the course of the last two decades that *SC* and *PUS* have been publishing research articles, there has been a consistent and steady increase in the output of articles related to the science engagement and science citizenship (SESC). Topics relating to the scientists' with the media and public (SRMP) also showed noted increases in output and subsequently steadying during the past ten years. Research related to public understanding of science and science literacy have remained relatively constant within the range of five to ten articles produced in each 3-year period. The topic of public knowledge and understanding of science is an important and arguably necessary prerequisite to engaging the public in becoming more active and invested citizens in the scientific process (Schafer, 2012). During the past two decades, this topic has remained relatively constant in its research output, indicating that it remains an important topic, but lower in output compared to research related to science engagement. In conjunction, research related to scientists' relationship with the public and media has also, though at a lesser rate and output, increased in number. The trend of increased science engagement with the public aligns with moving from deficit models of science communication to more interactive discussion, reflected in the increased output in SESC and SRMP related to science engagement and scientists relationship with the public, respectively.

As science communication research continues to delve more into how the field can engage the public in discourse recognizing that both the public and science communicators possess deficits in understanding the groups they interact with, there promises to be more research to address public engagement (Bauer et al., 2007). The increase in research regarding science engagement most likely indicates that science communication continues to grapple with how best to engage the public to increase science understanding as well as how the public can actively participate in science-related activities rather than continue with deficit-oriented avenues of consuming science (Seakins & Dillon, 2013). The roles of scientists in communication also will continue to require clarification as they shift from the role of experts in the deficit-oriented model of communication to participants in the public engagement process (Lewenstein, 2011; Stocklmayer & Bryant, 2012). Reflecting increased focus on public engagement, other outlets beyond *PUS* and SC have also recently promoted articles such as a 2014 issue of "*Understanding the Public Understanding of Science: Psychological Approaches*" in *Educational Psychologist* or the emergence of *Public Communication of Science and Technology (PCST) Network* to promote public understanding of and engagement with science. As these trends indicate, increased interactive and engaged models of science communication will continue to be an area of interest for future studies that can build upon understanding the complex interactions of science with society (Baram-Tsabari & Lewenstein, 2017).

Theme IS: Issues in Science

In regards to the themes of Issues in Science, research trends analysis is less pronounced, but there is still an increase in research in this theme. In Issues in Science, there are two main topics. Topics in BNM (Biotechnology and Nanotechnology in Media) and CCDP (Climate Change and Disease Perceptions) have seen upticks in their research output, indicating that research related to climate change as well as biotechnology remain and continue to be more frequently discussed and relevant topics. The relevance of these topics is indicated by constant exposure to news and discussions related to climate change as the yearly temperatures around the world continue to break records and debates regarding climate change coverage continues (Busch, 2016). Biotechnology and nanotechnology continue

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to garner more interest in popular news outlets (Acarli, 2016), given technological breakthroughs and the potential impact that these technologies can have on peoples' lives and bodies (S.-F. Lin, Lin, Lee, & Yore, 2015). The general upward trend for the topics in this theme indicate that issues generated in science remain intensely researched or discussed. BNM and CCDP topics, as seen in Figure 3, are mostly unrelated in content indicated by their distinct spacing on the topic map. Political, socio-cultural, or international events such as the release of science-related documentary "*An Inconvenient Truth*" could trigger interests in topics among constant media coverage and could have played a role in the discussion of climate change (Busch, 2016; Zimmerman & Bell, 2014). Advancements in body-modifying treatments or other controversial ramifications of cutting-edge technology can likewise trigger changes, positive and negative, in research focus (Kempner, 2008). These two of research, while present and consistently relevant to science communication, could also be present in other enclaves of discussion such as widely accessed news outlets or in broader media such that academic research does not target (Friedman et al., 1999).

Overall, the increased research output in science education related to conceptual change as well as socio-scientific issues is complementary to research output in science communication relating to public engagement in science as well as public attitudes towards science. These trends indicate an available space for cooperation and increased dialogue between the fields' researchers given that understanding conceptual change and how individuals learn best is affected by the way scientific experts or communicators convey or frame science content (Theme PES and MS). Also, increased research in socio-scientific issues is concerned with how science is represented in media and how science educators may utilize to engage the public. The fields of science education and communication have developed independently and have largely kept to their own respective communities (Baram-Tsabari & Lewenstein, 2017; Feinstein, 2015), but in the most recent decade, as we have witnessed and analyzed drastic upticks in research, science communication and education continue to share broad and specific goals of engaging the learners in classroom and with the public to promote engagement in a more collaborative manner (Mercer-Mapstone & Kuchel, 2017). This convergence points to the idea of a field of "Science-Edu-Communication" as an area of great potential (P.-H. Wu, Wu, & Chang, 2016). There exists a substantial space for educators, media, and those that specialize in mediating between the scientific community and the public to collaborate and further broaden scientific literacy.

Conclusions

It was confirmed in this research that scholarly output of science communication has trended toward a sharing goal of science education: promoting public understanding of science via ways of public engagement of science and media representation of science. This research also found that there was much complementary space for further collaboration with science communicators as the field increasingly focuses on research aligned with Public Engagement (Theme PES) and Media (Theme MS). Science education's research on conceptual change, socio-scientific issues and learning contexts, were also complementary with science communications' focus on science engagement and public attitudes towards science as expertise in both fields only serves to enrich increasing scientific understanding and literacy.

Therein exists a crucial need for science education to play a role in the future science communication development. Changing the perception of science in the public and in educational settings remains fundamental in engaging the public and thus collaborations with science education researchers is an area of promise. In the future, with increased research collaboration between science education and communication trends studies to quantify linkages in the two fields will be possible. This applies especially to the fields that would benefit from understanding of how media portrays the science and how to best educate unfamiliar audiences with science content. Also, as more avenues such as journals, conferences, and increased catalogues of research related to "science edu-communication" are made available, researchers can further depict the direction and overall findings of the interdisciplinary research field.

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Leon Yufeng Wu	PhD, Assistant Professor, Chung Yuan Christian University, 200 Chung Pei Road, Chung Li District, Taoyuan City, Taiwan 32023, R.O.C. E-mail: leonyifengwu@gmail.com
Nathan M. Truong	MA, Research Assistant, National Taiwan Normal University 88 Sec. 4, Ting-Chou Road, Taipei, Taiwan 11677. E-mail: truong.nathan@gmail.com
Hsin-Yen Lu	MA, Research Assistant, National Taiwan Normal University 88 Sec. 4, Ting-Chou Road, Taipei, Taiwan 11677. E-mail: happysky0323@gmail.com
Yuen-Hsien Tseng	PhD, Professor, National Taiwan Normal University, No.162, Sec. 1, Hoping East Rd., Da-an District, Taipei 10610, Taiwan. E-mail: samtseng@ntnu.edu.tw
Chun-Yen Chang *(Corresponding author)*	PhD, Professor, National Taiwan Normal University, 88 Sec. 4, Ting-Chou Road, Taipei, Taiwan 11677. E-mail: changcy@ntnu.edu.tw Website: http://changcy.com/

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