A Systematic Map of Inclusion, Equity and Diversity in Science Communication Research: Do We Practice what We Preach?

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Effective engagement with diverse stakeholders, combating misinformation and encouraging wider participation in science is core to science communication practice, and comprises much of the current focus of research in the discipline. Global events, such as the COVID-19 pandemic, have clearly shown that social inequalities also manifest within communication structures, including those of science communication. Practices which are inclusive of diverse audiences are key if we wish to engage diverse audiences in finding solutions to societal issues. Yet there is little available evidence to show which diverse, marginalised and/or excluded groups are being engaged within science communication, and *via* what means. This paper develops a systematic map of academic literature spanning 40 years to provide a preliminary evidence base of how diversity and inclusion within science communication research and practice is conceived and implemented. Although the discipline has shown an increased focus within the last 5 years, science communication must evolve further in order to develop a robust evidence base for understanding what constitutes inclusive science communication in both theory and practice.

Keywords: audience, diversity, engagement, equity, inclusion, intersectionality, science communication

INTRODUCTION

Modern science communication has a number of roles in society (Fischhoff and Scheufele, 2013; Davies, 2021), including – but not limited to – effectively engaging with diverse stakeholders (Weingart and Joubert, 2019), combating misinformation (Goldstein et al., 2020), and encouraging wider participation in STEM (Bevan et al., 2020). Since the emergence of COVID-19, "engaging with diverse stakeholders" and "combating misinformation" have been ever-prevalent roles. COVID produced an unprecedented demand for information, creating what the World Health Organisation termed an "infodemic"; "an over-abundance of information – some accurate and some not – that makes it hard for people to find trustworthy sources and reliable guidance" (World Health Organisation, 2020, p. 2). However, there were clear examples of how even "trustworthy" and "reliable" sources were not serving the needs of all community members. Park et al. (2020) found that over half of surveyed Australians had encountered COVID-19 misinformation at least "some of the time" – a figure likely underestimated as audiences need to recognise it as misinformation in the first place (Nurse et al., 2021). These unmet information needs were a major contributing factor to some of the detrimental outcomes for marginalised groups in Australia. The national multicultural broadcast network, SBS, reported that members of their audience were more likely to adopt

ineffective prevention, perhaps based on the belief they could ignore public health advice (Mara, 2020). The broadcaster argued that this could have been addressed by providing better, more appropriate, culturally targeted information (Mara, 2020). Minority groups are more likely to have difficulty accessing and understanding health information which can lead to gaps in communication (Blumenshine et al., 2008) and – at least in the case of COVID-19 – consequently a greater risk of infection and transmission (Tai et al., 2021) The challenges of the COVID-19 pandemic showed, in stark relief, the inequalities inherent within our societal and corresponding communication structures (O'Sullivan et al., 2020). Science communication also operates within these structures, and can reinforce some of these same inequities.

Science communication practitioners themselves note that the field tends to use a "Western, white, ableist and patriarchal" approach (Canfield and Menezes 2020, p 13), a description somewhat supported by a review of the existing science communication research by Guenther and Joubert (2017). Among attempts to address this problem, inclusive science communication has increasingly been suggested as a necessary framework (Bevan, Calabrese Barton and Garibay, 2020), bringing notions of inclusion and equity to existing science communication techniques and reflexive visions of how the field should progress both in academic and practical senses. Emily Dawson (2019) shows, in detail, ways in which science engagement continues to be inaccessible to many historically excluded groups. Earlier studies (e.g. Manzini, 2003) have similarly shown how well-intentioned inclusion activities fall into the trappings of the deficit model (Gross, 1994). This starts with the assumption that excluded groups have the "wrong" priorities around their needs, wants, interests and activities (Dawson, 2019) – an approach that disregards cultural history and nuance (Hogarth, 2017). Science communication, like science itself, is shaped by social forces including but not limited to gender, race, class, access to power and language (Lewenstein, 2019). As science communication researchers and practitioners, we bring our own cultural perspective to our practice and research, and it is useful to interrogate how our personal perspectives shape our work (Halpern, 2019; Polk and Diver, 2020). But do our personal perspectives allow us to be reflexive practitioners, capable of developing programs and initiatives that are truly inclusive and fit-for-purpose according to the needs of the diverse, and some traditionally underserved, audiences in our communities?

While the concept of inclusive science communication is not new (Massarani and Merzagora, 2014) there has been renewed interest within the last decade. Although the ideas of equity and inclusion are being more consistently raised in discussions of science communication theory and practice, there is little evidence to show exactly how science communication – and science communicators – define inclusion, whether they engage diverse audiences or not, and if so, how. This paper will present the results of a systematic map of 40 years of science communication literature, providing an empirical overview of how diversity and inclusion within science communication research and practice is defined and implemented.

Literature Review

Matters of equity and inclusion have received increased attention with 2020's Black Lives Matter movement coinciding with the COVID-19 pandemic and its inequities at local and global scales (Olzmann 2020). Academic interest in equity and inclusion as a starting place for high quality scholarly work across diverse fields has also recently increased to unprecedented levels (e.g. Khan et al., 2021). However, a significant historical limitation is the geography of scholarly work, with much study about inclusion and exclusion in science coming from North America, Western Europe and other Western countries including Australia and New Zealand, though this does not necessarily reflect the patterns of inclusive practice (Irwin, 2014).

Historical Exclusion

Feinstein and Meshoulam (2014) remark that equity – especially in practice – looks different for every organisation, with different contexts, local histories, challenges and individual perspectives influencing what is needed by the community. Attempts to address these needs are not always easy, or successful. Take gender equity in science as an example. Increased gender diversity without strategic underpinning has not resulted in major changes to the way science communication – or indeed science – operates in terms of progressing gender equity in leadership, policy or legislation (Rasekoala, 2019). Science communication, in contrast to STEM in general, tends to have a greater proportion of women working in the discipline, especially in lower ranked roles. Consequently the field is perceived as more feminine and lower status than science, yet men still tend to outnumber women at senior levels and in higher status roles (Rasekoala, 2019), mirroring what is generally seen in STEM disciplines more broadly. Despite decades of initiatives, research and attention to increase the attraction, retention and progression of girls and women in science, technology, engineering and mathematics studies and careers, inequities still exist and persist (e.g. Larivière et al., 2013; UNESCO, 2015; Holman et al., 2018; Potvin et al., 2018; Australian Academy of Science, 2019). The reasons are complex, including stereotypes (Steele, 1997), personal versus family and societal expectations (Sassler et al., 2017), and structural barriers (e.g. Miner et al., 2018), to name just a few.

While gendered exclusion from science is well-studied, women are not the only community who face barriers to participating in science. Science is subject to the Matthew Effect (Merton, 1968), where those with high science capital (Archer et al., 2015) have better access to science enrichment, including science education and careers (Holmes et al., 2018; Patfield et al., 2021). This includes class as a factor, with a study from the UK finding that the likelihood that students would persist with post-compulsory science study was stratified by class (Gorard and See, 2008). Literature examining how low-socioeconomic status individuals and communities have been excluded from science participation have generally looked at income as just one of several factors interacting to maintain exclusion (Dawson, 2014a, 2018; Medin et al., 2017). Exclusion due to race or ethnicity has been well studied (e.g. Asai, 2020), with research showing impacts on scientists of colour occurring and persisting

from childhood (e.g. DeWitt et al., 2011) through higher education (e.g. Avila, 2019), and into the workplace (e.g. Ginther, 2018).

Indigenous peoples have also faced exclusion, from traditional knowledge being regarded as inferior to Western scientific knowledge (e.g. Rigney, 2001; Singh and Major, 2017; Bang et al., 2018) though a limited number of outreach initiatives aim to remedy this with communities (e.g. Tzou et al., 2019). Doctoral study – a key transition to academic participation – can be a culturally unwelcoming experience for Indigenous peoples, as recounted in the personal perspective of Melitta Hogarth (2021), an Australian Aboriginal academic. Limited evidence from the UK (Sang et al., 2021) shows academic science participation for people with a disability can be similarly structurally limited, due to a number of factors including workplace policies and organisations' resources to implement them. People with a disability are under-represented in STEM, and generally take longer to find employment (Hawley et al., 2014). Sexual minority (for example, lesbian, gay, bisexual or queer-identifying) students are less likely than their heterosexual peers to complete tertiary STEM studies (Hughes, 2018), while LGBT+ STEM professionals in the UK reported that many felt unsafe, unsupported or excluded in their workplaces (Dyer et al., 2019). While women have been a fairly well-studied group in terms of gender as previously described, accounts of non-binary, transgender and gender diverse people's experiences in science seem to be limited to individual case studies (e.g. Barres, 2006; Pérez-Bustos, 2014).

English is recognised as the language of science (Gordin, 2015), and this dominance across both science and science communication excludes or disadvantages non-English speaking peoples (Márquez and Porras, 2020). Immigrants can find science communication inaccessible due to low literacy, low scientific literacy, and a poor understanding of the "rules" to be able to engage "correctly," each compounding exclusion (Dawson, 2019). This idea of multiple factors – or identities – compounding exclusion, and thus also increasing complexity in creating inclusive practice, will be further discussed later in this literature review.

Communicating With an Audience

Knowing your audience and responding to their needs is well established best practice in science communication, along with not simply taking what works in one context and applying the same strategy to a separate environment without scrutiny (Fischhoff and Scheufele, 2014). But this does not get to the deeper issue of engaging historically excluded and marginalised audiences. The term marginalised could be interchangeably used with minoritised, referring to groups that are actively diminished by others rather than existing as a minority (Gunaratnam, 2003). This goes beyond the often cited challenge of "engaging the unengaged" in science communication, instead encompassing the underlying and often systemic reasons for an audience's "unengagement"; specifically of not feeling that they are welcome, included or that the content will be relevant to them (Archer et al., 2016; Dawson, 2019; Humm and Schrögel, 2020).

Researchers have noted that some science communication activities may reinforce, rather than address existing societal inequities (Bevan et al., 2020). For example, common science communication experiences such as science museum visits can uphold perceptions that science is only for a certain type of person – often perceived by marginalised groups as "not for us" (Dawson, 2019, p. 61). Thus well-intentioned but poorly designed and delivered activities can perpetuate ongoing oppression and exclusion through "othering" and expectations of assimilation rather than meeting people where they are (Streicher et al., 2014) and accepting engagement on their terms (Boutte and Jackson, 2014; Dawson, 2019; Bevan et al., 2020).

Dawson (2014b) notes that while short-term science communication and engagement projects or interventions are a valuable testing ground for inclusive practice, they are limited in their scope and impact toward systemic change. Indeed, Banerjee (2017) found that one-off or short-term STEM enrichment and enhancement programs had no effect on whether school children went on to pursue STEM at higher levels. (Bevan et al., 2020, p. 2) note that the "celebrity status" of promising interventions belie their reliance on passionate individuals and unsustainable short-term funding. Dawson (2014b) asks how to move from relying on the more common short term projects to creating the kind of environment where they are redundant, and this question seems to remain largely unanswered.

Those with privilege and power to create change in the way that science communication is practised also need an evidence-based understanding of how to effectively create inclusive science communication. These understandings are less developed, however some notable progress has been made in the last few years. The 13th International Public Communication of Science and Technology Conference, held in 2014, featured *Science communication for social inclusion and political engagement* as the main topic, tapping into, at the time, emerging work in this area and bringing the relationship between science communication and social inclusion into sharp focus (Massarani and Merzagora, 2014). The Equity Compass, developed by The YESTEM Project UK Team (2020), is a good example of a practice-focused tool to support practitioners. Clear, directed reflection prompts guide practitioners to critically analyse, evaluate and increase equity and justice in science communication projects. The Equity Compass is just one part of the YESTEM equity model, which describes reflection and actions working together to influence outcomes for the individual audience, the practitioner, and the organisation (YESTEM Project UK Team, 2020). This idea of reflection and action working together is a key aspect of reflexivity (Salmon et al., 2017). A recent special topic in Frontiers in Communication has also shone a light on inclusive science communication practice and theory (Hayden et al., 2020) with a range of papers exploring ideas including, but not limited to, identity (e.g. Neeley et al., 2020), inclusive language (e.g. Bevan et al., 2020; Márquez and Porras, 2020), culturally responsive science communication (e.g. Carlisle, 2020; Gray et al., 2020; Landis et al., 2020), activity evaluations (e.g. Curry and Lopez, 2020; Polk and Diver, 2020), participant experiences (e.g. Smith et al., 2020), barriers to inclusive science communication practice

(e.g. Roca et al., 2020) and challenging the status quo (e.g. Bevan et al., 2020; Gray et al., 2020). This collection is all comparatively recent and contributes important information and insight to science communication research and practice alike. But are these the extent of inclusion focused work in the discipline? As a discipline, we require evidence that our research and practice is inclusive and equitable, enabling us to best serve our societal role for all people within our society.

Inclusion in Science Communication Research and Practice

While the type of major systemic and cultural change required to see equity and social justice in the science communication field is important (Canfield et al., 2020), it will take time, resources and collective will (Schell et al., 2020). This is a space where evidence-based science communication, bringing together the best of research and practice (Jensen and Gerber, 2020), could have a substantial impact. Clear, available data is one path towards equity, reform and justice (Ong et al., 2011). Although this literature review has already shown evidence of existing work aiming to identify barriers, gaps and opportunities, there does not appear to be a complete picture of how science communication has examined and incorporated inclusive practice to date.

Part of the problem arises due to the seeming lack of a consistent understanding or definition of terms such as equity, equality, diversity and inclusion. These phrases have somewhat varied and loaded meanings and understandings, that can cause struggle and confusion (Bisbee O'Connell et al., 2020). Putnam-Walkerly and Russell (2016) found that many organisations using equity as a guiding focus did not have a clear definition of what equity is, using a "gut feel" instead. Even the idea of inclusive science communication has varied names. Some authors specifically refer to "socially inclusive science communication" (Massarani and Merzagora, 2014, p. 1) but do not specify what this means in practice, whereas others use descriptors such as "effective science communication" (Manzini, 2003, p. 191) or "science for all" (Humm and Schrögel, 2020, p. 1), which are less specific again in a social inclusion context, yet similar ideas are presented.

Bringing a global south perspective to these matters from a public health background, Olusanya et al. (2021) define equality as understanding that all people are equal though unique and complementary – regardless of gender, race, disability, socio-economic status, or nationality – while equity is a commitment to specific action. Equity is a process of reprioritising opportunities and support to reduce or eliminate systemic imbalances and barriers to power, education, information or resources (Canfield and Menezes, 2020). With science communication as an important – and for some individuals and communities, the only – interface between science and society (Scheufele, 2013), equality and equity are critical considerations in who gets to participate in science.

Different groups within the science communication sphere understand "inclusive" to mean different things, especially around who – and what needs – should be catered to, in some cases distinguishing different identities of marginalisation such as disability, race or gender, while others do not (Canfield et al., 2020). Quick and Feldman (2011) argue that inclusion is more than successful participation, and similarly diversity is not simply having a range of demographics. Rather, Quick and Feldman (2011) instead define inclusion with respect to both process and outcome, where inclusion is shown within projects which are built and refined through collaborative, ongoing and iterative relationships. An intersectional (Crenshaw, 1989) perspective on inclusion would recognise that a given individual's identities would have complex interactions in the way that they perceive and feel about science, as well as how those in power in science environments will perceive the individual. For example, in the US, women of colour have been shown to experience barriers that are unique and compound their experiences both as women and people of colour, with the result being greater than the sum of the parts (e.g. Carlone and Johnson, 2007; Ong et al., 2011). In an increasingly complex world of diversity, and even "superdiversity" (Thomas and Macnab, 2019, p. 3), intersectionality – understanding that an individual's needs are unique, rather than determined by the stereotypes of a single aspect of their identity – is a useful foundation for considering inclusion (Avraamidou, 2020).

Within science communication, Canfield and Menezes (2020) describe inclusive science communication practice as being intentional, reflexive and reciprocal, linked throughout by equity. For the purpose of this study, the intentional focus of inclusive practice will be a key indicator. However, other key terms – such as inclusion, diversity, equity and access – are accepted in their broadest sense amongst the literature to capture the variety of ways they have been used with parallel intentions.

Study Aim

This thematic special issue calls for evidence-based science communication. Within science communication, academics and practitioners can both generate evidence of effective practice. For the purposes of this study, we will adopt Jensen and Gruber's (2020) stance that science communication research should be providing insights which practitioners can use. This study will examine the academic peer reviewed literature in order to gain an overview of the "best available evidence from systematic research, underpinned by established theory" (Jensen & Gerber, 2020, p. 2). This approach, while not exhaustive, aims to provide a systematic map of science communication studies over a period of 40 years to explore how issues of equity, inclusion and diversity have been incorporated in theory and practice. This time scale has been chosen as it encompasses the influential 1985 Royal Society report on the public understanding of science, and a period of advancement of research and publishing in science communication, including the launch (or relaunch) of the discipline's most dominant academic journals (Trench and Bucchi, 2015). We expect that the later years will show greater prevalence of research topics concerned with equity and inclusion, however will they be focused broadly on a range of minoritised audiences, or will the focus be on a few? The overarching aim of this study is to provide a preliminary evidence base for inclusive science communication practice

and research, examining which audiences are typically served, where, and how. This will provide the data necessary to inform areas of future effort and research to create a truly inclusive approach to science communication.

METHODS

This study will employ a systematic map approach (James et al., 2016). A systematic map uses methods similar to a systematic review – considered to be the gold standard of evidence in many fields – but a systematic map aims to survey what evidence exists, rather than synthesising the results of many studies (Bates et al., 2007). The advantages of using systematic methods include the ability to reduce biases due to the systematic approach to identifying and categorising literature, the ability to confidently discern trends in the literature, and, importantly, a systematic map has the ability to ask an open question (James et al., 2016). Systematic approaches also enable a rapid identification of the diversity and range of existing research (Pickering and Byrne, 2014), key to the aim of this paper. We used a streamlined version of the methodology proposed by Pickering and Byrne (2014), omitting considerations such as weightings given to papers based on sample size and methods, to conduct the systematic map as described following.

Search Procedure and Inclusion Criteria

Articles were sourced using the databases Web of Science and Scopus. Original research articles were used as these are a primary source which have been through a peer review process (Pickering and Byrne, 2014). The search terms were kept intentionally broad, and the journal options open as science communication related work is not published exclusively in science communication journals. We also wanted to ensure that we captured as many factors related to intersectionality and inclusion as possible, so terms and acronyms related to different characteristics and audiences were also intentionally broad. Searches were limited to journal articles published between 1980 and 2020 in English. We acknowledge that restricting the search to English is in itself a process of exclusion, mitigated only by the use of English as the "*lingua franca* in the field" (Trench & Bucchi, 2015, p. 2). Future studies should incorporate research published in languages other than English to gain a more complete overview. Searches used the following search strings:

Scopus

TITLE-ABS-KEY ((scien* W/1 communication) OR (science W/1 engagement) OR "public understanding of science" OR "communicating science" OR (scien* W/0 outreach) OR "informal science learning" OR (science W/1 participation) OR ("public engagement" W/3 science)) AND TITLE-ABS-KEY (inclusi* OR "leaky pipeline" OR disadvantage* OR discriminat* OR divers* OR equality OR equity OR exclusion OR intersectional* OR minorit* OR oppress* OR social OR female OR feminist OR gender OR girl OR woman OR women OR "English as a second language" OR "non-English speaking" OR "people of colour" OR "people of color" OR

"person* of colour" OR "person* of color" OR "wom*n of colour" OR black OR blak OR bipoc OR colour OR color OR cultural OR esl OR cald OR immigrant OR linguistic OR *migrant OR multicultural* OR race OR refugee OR regional OR rural OR socio-economic OR indigenous OR aboriginal OR first AND nation* OR disab* OR neurodiverg* OR neurodivers* OR autis* OR lgbt* OR queer OR lesbian OR gay OR bisexual OR transgender OR transsexual) AND PUBYEAR > 1979 AND PUBYEAR < 2021.

Web of Science

TS=((scien* NEAR/1 communication) OR (science NEAR/1 engagement) OR "public understanding of science" OR "communicating science" OR (scien* NEAR/0 outreach) OR "informal science learning" OR (science NEAR/1 participation) OR ("public engagement" NEAR/3 science)) AND TS=(inclusi* OR "leaky pipeline" OR disadvantage* OR discriminat* OR divers* OR equality OR equity OR exclusion OR intersectional* OR minorit* OR oppress* OR social OR female OR feminist OR gender OR girl OR woman OR women OR "English as a second language" OR "non-English speaking" OR "people of colour" OR "people of color" OR "person* of colour" OR "person* of color" OR "wom*n of colour" OR black OR blak OR bipoc OR colour OR color OR cultural OR esl OR cald OR immigrant OR linguistic OR *migrant OR multicultural* OR race OR refugee OR regional OR rural OR socio-economic OR indigenous OR aboriginal OR first AND nation* OR disab* OR neurodiverg* OR neurodivers* OR autis* OR lgbt* OR queer OR lesbian OR gay OR bisexual OR transgender OR transsexual) Indexes = SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI, CCR-EXPANDED, IC Timespan = 1980–2020.

In each of the above search strings, the asterisk indicates a wild card search meaning that all possible variations of a word were included. For example, disab* would return results containing the words disable, disabled, disability, disabilities. W/n and NEAR indicates that the specified word (e.g. scien*) appears near or within the specified number of words to another specified word (e.g. scienc* NEAR/1 communication specifies that any word starting with scien is included if it appears within one word of communication; "informal engagement" W/3 science means the phrase informal engagement appears within three words of science etcetera). Searches used title, abstract and key words to identify relevant articles.

Initial searches yielded 2,280 articles from Scopus and 3,597 from Web of Science. A further 14 articles were included from additional sources identified by the researchers. The total 5,891 articles were uploaded into reference management system Mendeley and duplicates removed, leaving a total initial corpus of 5,455 articles. These were exported into Rayyan (http://rayyan.qcri.org) (Ouzzani et al., 2016), a web app designed to conduct collaborative systematic reviews.

Articles were then reviewed in two phases for inclusion or exclusion in the study. The initial review used the title and abstract to determine inclusion or exclusion. Articles were

**FIGURE 1 |** Overview of data collection process for systematic mapping.
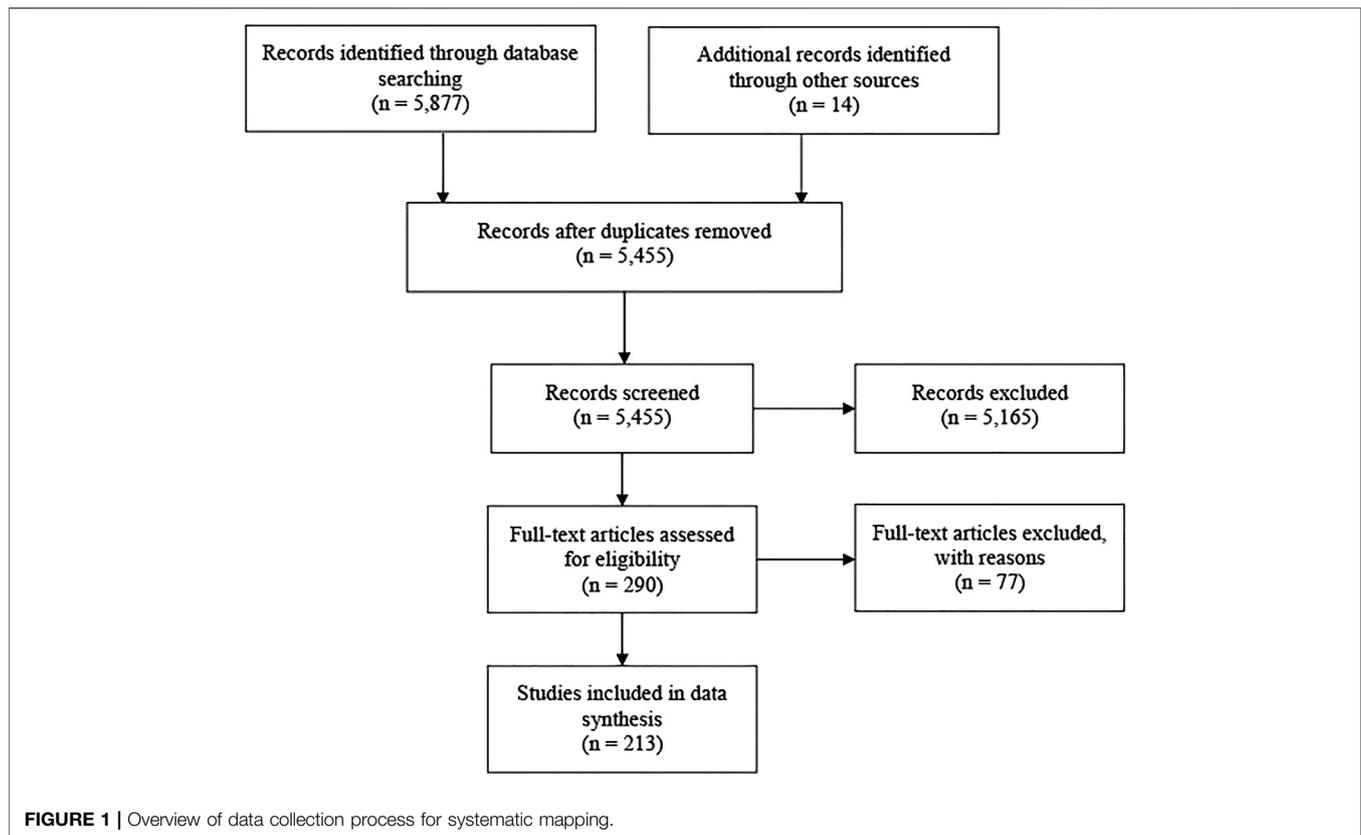
retained if they were about science communication within the parameters of the search strings (thus encompassed education, engagement, participation etcetera); if they related to the science/society interface; and/or if the study had an intentional focus on equity, inclusion and/or intersectionality. Articles were excluded at this phase if they were not articles published in peer reviewed journals, if they were published after 31 December 2020, not in English, if they were specifically about communication between scholars (e.g. open access publishing) or if the equity angle was not intentional (for example a general public survey that divided results by age and gender, but gender differences were not the focus of the study).

Both authors independently reviewed the articles. In the first phase, there was a conflict for 35 articles in the sample. These articles were discussed and resolved. At the end of the first phase, 290 articles were retained. During the second phase, the full texts of the articles were read. Articles were retained if they were intentionally focused on issues of equity, diversity and inclusion. The article had to have an intentional focus on a minoritised group, which could also be purely descriptive of their experience; and/or a science communication program/practice/other mechanism to support inclusion of minoritised groups. In this second phase, 54 articles were discussed and resolved. The number discussed was higher in this round as the intentionality of the study was not always easily identified, and a few studies were challenging to classify as "science communication" or not. For

example, two papers on the use of Indigenous names in taxonomy generated much discussion, with both subsequently included as the intention of the work was to include the Indigenous traditional knowledge and communicate that knowledge to a broader audience. After the second round of coding, 213 articles were retained for further analysis. A flowchart showing each step of the paper selection process is provided in **Figure 1**.

Data Analysis

The included article information was exported to a spreadsheet, with the full texts of the papers kept in both Mendeley and an online folder. A data extraction template was developed within Microsoft Excel to extract the key characteristics of each paper. These characteristics included the country where the study was located, the characteristics of the audience who were the focus of the paper (for example women, immigrants), the goals of the paper and the field of the paper (for example science engagement). The goals were developed inductively by one author, with a random sample of 10% of the dataset co-coded and verified by the other author. The paper fields were coded by the other author, with fields also developed inductively. Each paper was coded with one field (a primary field) and a secondary field was allocated to papers which may have spanned two fields (for example higher education and medicine). Each data extraction category code was continually refined throughout the extraction process, with both authors verifying the consistency and accuracy of the data.

FIGURE 2 | Number of articles published each year during the 1980–2020 sample period (*n* = 213).
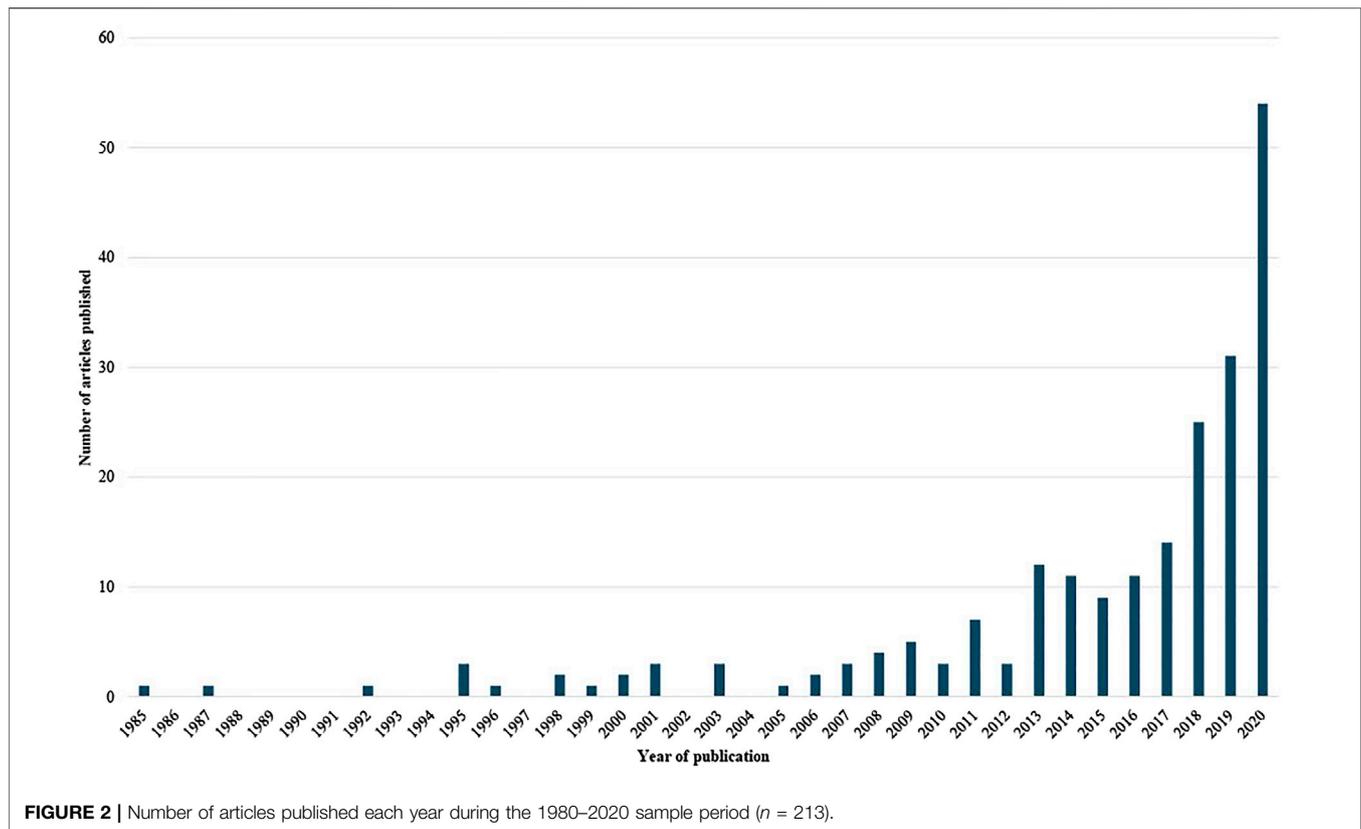
RESULTS
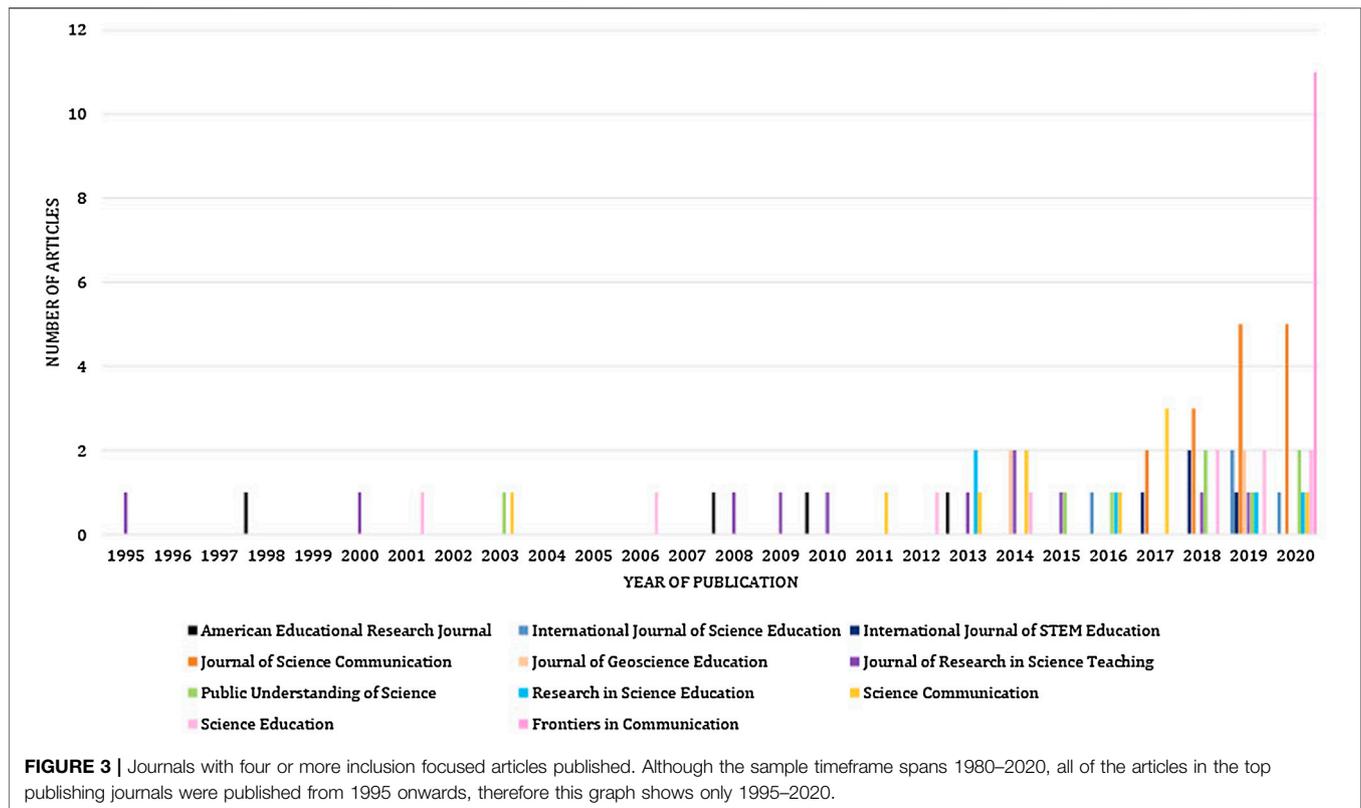
Included Paper Characteristics

A total of 213 papers from 117 journals were used in this analysis. Although the collection period was from 1980, the first included article was published in 1985. In the first 20 years of the sample (1980–2000), only 12 articles were published. Between 2001 and 2010 a further 24 articles were published. From 2011–2020, 178 articles were published, with the majority (*n* = 135) published between 2016 and 2020 (**Figure 2**). The majority (*n* = 15) of these articles were published in the Journal of Science Communication (JCOM), with the Frontiers in Communication and the Journal of Research in Science Teaching each publishing 11 articles, and Science Communication and Science Education publishing 10 articles each (**Figure 3**). The Public Understanding of Science was the last science communication focused journal in the top publishers, producing eight articles. The remaining "top" publishing journals all had an education focus, which extended into the remaining journals who published two articles in the sample period. The bulk of the sample (89 journals) published one article only during the sample period. The full list of journals and the number of articles published is available upon request from the corresponding author.

The geographic focus of each article was identified and coded. These are presented in **Table 1**. Articles were coded as "global" if they were reviews of a topic or used data from the internet such as comments on social media channels. The majority (*n* = 99) of articles were United States (US) focused, with global papers a distant second (*n* = 27). The United Kingdom (UK) had 22 papers. The sample included seven multinational papers that spanned several regions (for example North America, Europe, Southeast and East Asia) and the same number from Australia. All other regions had four or fewer publications. Taking geographic regions as a whole, almost half of the sample (102 articles, 47.89%) came from North America. Europe had the next greatest segment (31 articles, 14.55% of sample) closely followed by globally focused papers (27 articles, 12.68%).

Audience

For each of the included articles, audience categories were developed based on the stated aim of the paper or the description of the population sample. Papers could have more than one audience. For example, many papers from the US referred to under-represented minority groups. This typically included African American, Asian American, Native American/ Indigenous, Latinx and Hispanic people. Depending upon the paper context, some papers included women in their definition, or excluded Asian Americans. The included minority groups were usually (but not always) explicitly defined in a footnote or described in the method. These were not always consistent so individual groups within these minority groups were recorded. Where groups within the broader "under-represented minority" description were not specified, all groups listed above were considered to be included. Audience categories were added and refined as they were identified, leading to the following list:

FIGURE 3 | Journals with four or more inclusion focused articles published. Although the sample timeframe spans 1980–2020, all of the articles in the top publishing journals were published from 1995 onwards, therefore this graph shows only 1995–2020.

- Girls/women.
- Black – typically African American.
- Indigenous – Australian or Canadian Indigenous peoples, First Nations, Native American, Maori.
- Asian – often Asian American but also people of Asian backgrounds living in non-Asian countries.
- Latinx/Hispanic – People from Latin America and Spanish speaking nations, often – but not exclusively - in this sample referring to communities located in countries (e.g. USA) outside of this geographic region.
- Immigrant.
- Linguistically diverse – often appeared with immigrant
- Disability – physical, visual or audial impairment, developmental disability or neurodiversity.
- Religious groups/castes – groups with shared belief systems or socially stratified characteristics.
- Low socio-economic status – including schools/students who qualify for reduced or free lunches; included any papers referring to "working class" groups.
- Implementers – people with the ability to influence or implement the adoption of inclusive practice.
- Developing nations.
- Incarcerated people – groups living within correctional facilities.
- LGBTQ* - encompassing all forms and expressions of gender identity and sexuality.

Of all audience groups, girls/women appeared most commonly ($n = 97$, *see* **Figure 4**). Implementers were the

second most common audience, with 48 papers "speaking" to other practitioners and/or researchers. The "under-represented minority groups" appeared in similar numbers as many papers bundle these audiences together, with the exception of Asian audiences that were less frequently included. Papers from the UK in particular focused on communities from low-socioeconomic areas. A small number of papers looked at very specific – and arguably under-served – audience groups, namely those with disabilities ($n = 18$), developing countries ($n = 16$), religious or caste identities ($n = 3$) and those in prison ($n = 1$).

Paper Goals

Each article was read to determine what it aimed to present. Iterative development created the following categories:

Review – a synthesis of literature and/or data to provide an overview of the key issues, opportunities, and/or implications. Did not involve any data collection with specifically recruited participants.

Audience experience – original research exploring the experiences of audience/s in science communication practices such as presenting on YouTube or blogging. Could also include garnering input from particular communities or groups to inform practice or to develop research instruments (e.g. surveys). Can include testing of contributing/interacting factors which influence factors such as identity and beliefs. Does not explicitly aim to determine impacts or outcomes.

TABLE 1 | Comparison of country of focus for included articles.

Country of article focus	Number of articles	Regional total	% of sample	Total per region	% of sample
Africa					
Nigeria	1	7	3.29	7	3.29
South Africa	4				
Tanzania	1				
Multinational	1				
Asia					
Multinational within Asia broadly	2	18	8.45	18	8.45
Central Asia					
Tibet	1				
East Asia					
Japan	4				
Taiwan	1				
South Asia					
India	4				
Southeast Asia					
Timor Leste	2				
Thailand	2				
Vietnam	1				
Western Asia					
Israel	1				
Caribbean					
Multinational	2	2	0.94	2	0.94
Europe (including United Kingdom)					
Austria	1	31	14.55	31	14.55
Germany	3				
Luxembourg	1				
Norway	1				
Switzerland	1				
UK	22				
Multinational within Europe	2				
North America					
Canada	3	102	47.89	102	47.89
United States	99				
Oceania					
Australia	7	13	6.10	13	6.10
Fiji	1				
New Zealand	4				
Multinational	1				
South America					
Brazil	2	6	2.82	6	2.82
Multinational (Latin America)	2				
Colombia	2				
Multinational across regions (specific country focus)	7	7	3.29		3.29
Global (no specified geographic focus)	27	27	12.68		12.68
Total	213	213	100%		

Evaluation – research evaluating the impacts/outcomes of programs, projects or events on inclusion and identity formation, including those specifically designed to create an inclusive environment or prioritise inclusive practice.

Recommendations – Recommendations, toolkits for science communication practitioners to adopt/enhance inclusive practice and create inclusive environment. The recommendations are the specific focus and function of the research or case study presented.

Perspective – article describing perspective or opinion of a particular audience through a first-person narrative but does not provide recommendations for practice or present original research data.

The majority of articles (*n* = 202) were coded within a single goal category. The remaining papers typically belonged in two categories with one paper spanning three. Of all articles, the most common goal of a paper was to present the experience of an audience (*n* = 76; *see* **Figure 5**). This tended to be descriptive of students in classrooms or informal science education settings, particularly "identity work" and factors influencing interest and engagement. Sixty-six articles outlined some form of evaluation. This could be a long-term evaluation of student outcomes from a mentoring/pipeline support type program encouraging under-represented groups into health and science disciplines; the impact of mentors or role models on perceptions and stereotypes or the effectiveness of a particular pedagogical approach in engaging
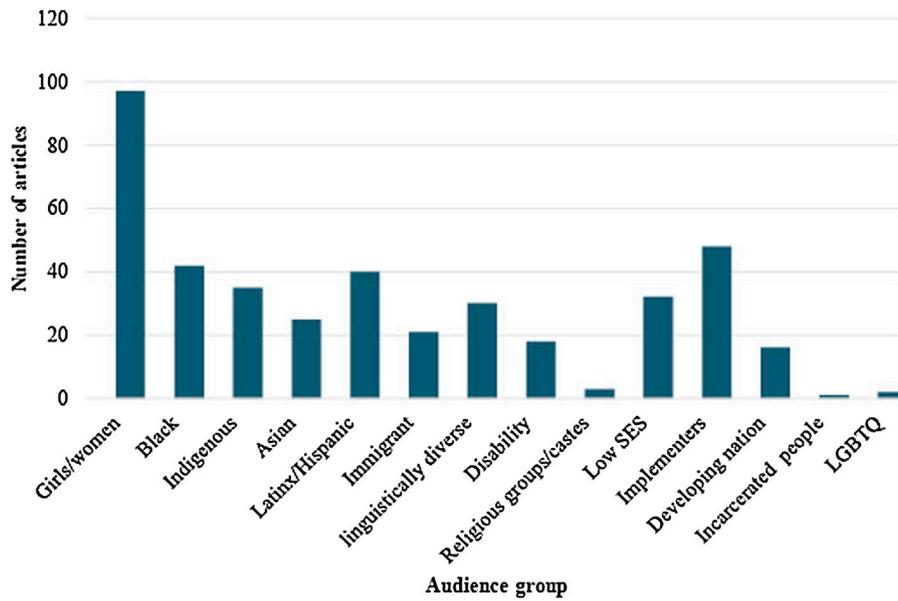
FIGURE 4 | Comparison of audience groups focused on in articles (*n* = 213). Articles could have more than one audience focus.
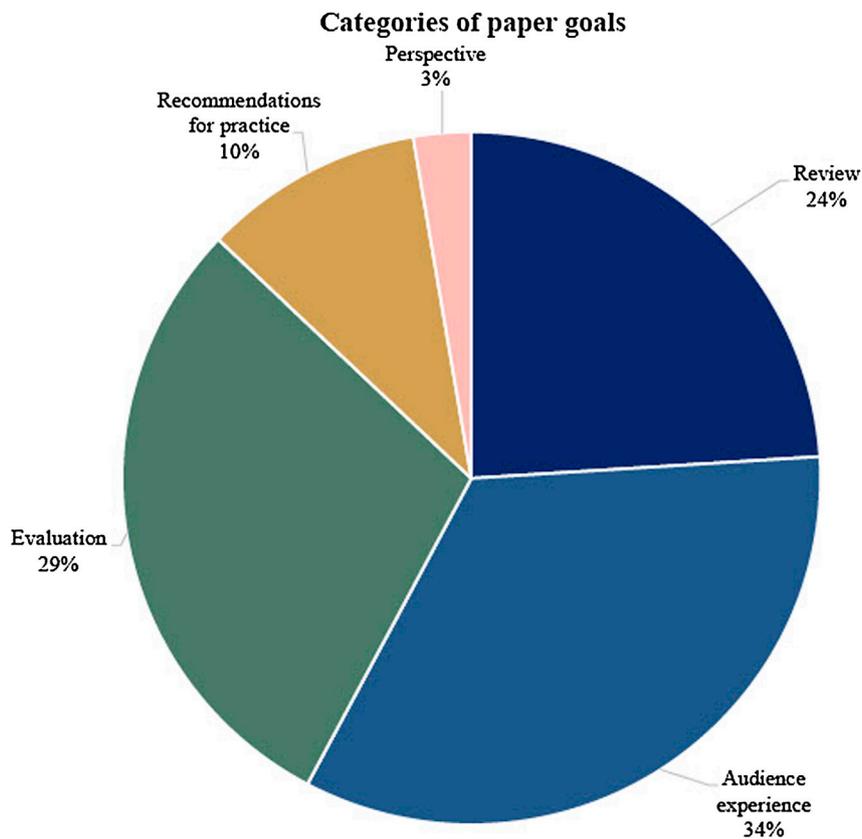

FIGURE 5 | Composition of paper goals within included articles. Eleven (11) articles had two or more identified goals, meaning the total count exceeds the sample size (*n* = 213).

TABLE 2 | Comparison of audience and paper goals.

Audience	Paper goal					
	Number of articles	Review	Audience experience	Evaluation	Recommendation	Perspective
Girls/Women	97	29	33	33	13	3
Black	42	5	15	24	0	0
Indigenous	35	9	12	13	4	0
Asian	25	2	11	12	0	1
Latinx/Hispanic	26	3	5	16	2	1
Immigrant	21	3	13	4	1	1
Linguistically diverse	16	3	13	4	1	1
Disability	18	2	6	6	4	0
Religious/caste	3	0	3	0	0	0
Low-socioeconomic status	32	7	11	14	0	0
Implementer	48	25	9	3	18	2
Developing nation	16	6	6	3	0	1
Incarcerated	1	0	0	1	0	0
LGBTQ*	2	0	0	1	0	1

students in formal or informal education settings. A smaller number of papers also evaluated workshops and conferences intended to build inclusive capacity in scientists and science communicators. About one quarter of the articles were coded as reviews of particular topics or issues, often using existing datasets of student enrolment or standardised tests, or presented literature reviews of issues pertaining to inclusion. While the majority of academic papers do make recommendations for future research or indeed practice, these tend to occur at the end of a paper and arise from the study rather than exist from the outset as the reason the study was done. The recommendations category is for those papers that had the sole focus on giving recommendations, aiming only to provide very practical, tangible guidance and suggestions for creating more inclusive environments and practice. Under 10% of the articles focused on making recommendations. This included papers which provided detailed guidelines on how to make spaces physically accessible, how to work with Indigenous community groups, how to present materials to ensure accuracy and accessibility for visually impaired people and how to run an inclusive conference.

Table 2 outlines how the different paper goals aligned with different audiences. Across all audiences, papers which focused on audience experience and evaluation were most common. Girls/women and implementers were most likely to be the focus of reviews. Perhaps unsurprisingly, papers aimed at implementers were also more likely to be recommendations. Girls/women also were the leading focus of recommendation papers with all other audiences the focus of less than a handful of recommendation papers, if they had any at all. Very few papers across all audiences were perspectives.

Paper Fields of Research
As observed in the journals represented in the final sample of articles, some fields and types of science communication were seemingly over- or under-represented. To quantify this, an additional round of coding sought to understand the types of work represented amongst the articles in this study. The iteratively developed list of categories comprised:

Science education (HE) – papers concerning science education in higher education settings, including student participation data, course evaluations, student mentoring programs and science achievement.
Science education (HS) – papers concerning science education in high/secondary school settings, including pedagogy, curriculum, science achievement and classroom dynamics.
Science education (PS) – papers concerning science education in primary, elementary or middle school and pre-school or kindergarten settings, including pedagogy, curriculum, science achievement and classroom dynamics.
Professional development – papers concerning employee upskilling opportunities, including mentoring for professionals, conference workshops, science communication or writing training for STEM professionals.
Science communication practice – papers concerning practical ideas, project descriptions or recommendations for public facing science communication including science centres and museums, science festivals or public science workshops (including for targeted communities). Includes work around public understanding of science or specific strategies for communicating scientific ideas. Includes science writing, including science blogging, science journalism and other science-related work in written media, and those who produce such works. Distinct from *STEM engagement* by the focus on practitioners and delivery rather than audience experience.
Science communication theory – papers concerning theoretical advances in science communication, including models or frames for understanding or analysing science communication work.
Science policy – papers concerning the making and communication of government policies concerning scientific content.
STEM workforce characteristics – papers concerning the makeup of the STEM workforce, including those who do science communication, STEM postdocs, and STEM professionals in academic or other workplaces.
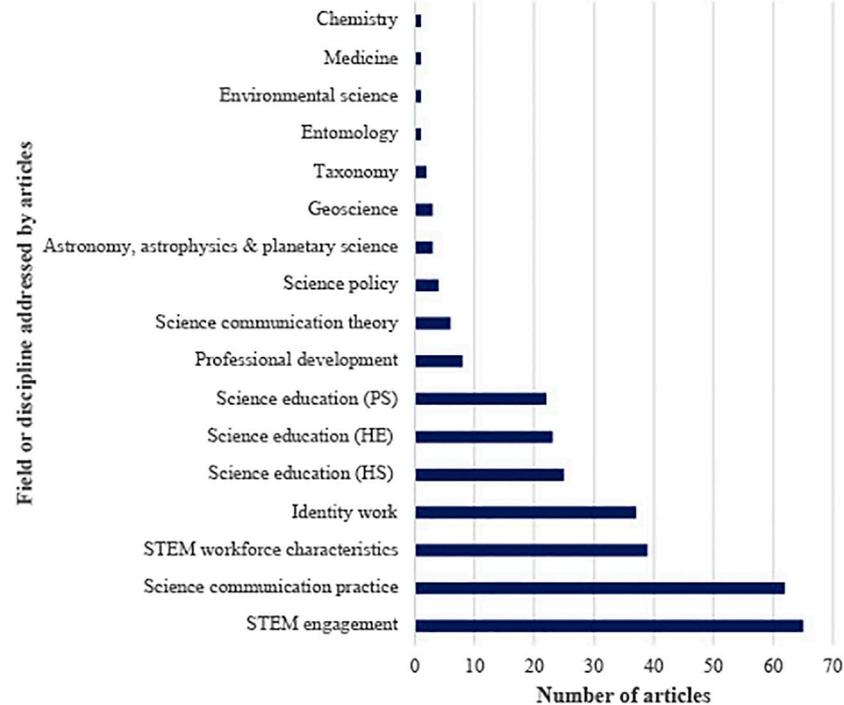
FIGURE 6 | Fields of study of articles in sample. Ninety (90) articles had both a primary and secondary field, with the remainder having only a primary field, so the total count of fields exceeds the sample size (*n* = 213).

Identity work – papers concerning the formation or understanding of individuals' identity or identities, including but not limited to science, gender or cultural identities, that generally draw on a combination of theoretical frameworks from fields such as psychology, sociology and anthropology.

STEM engagement – papers concerning a range of activities that aim or serve to understand or increase "engagement" in science, generally defined as attitudes towards science or desire to participate in future science activities such as attending a science fair or museum, or, especially for young people, aspiration or self-efficacy towards science careers or senior studies in science. Distinct from *science communication practice* by the focus on audience experience rather than practitioner experience.

A number of distinct academic fields were also included as codes:

- Environmental Science.
- Geosciences.
- Entomology.
- Astronomy, astrophysics and planetary sciences.
- Taxonomy.

Categories in this list did not include methods such as ethnography or econometrics.

Papers were assigned a primary and optional secondary field. Combinations of these two fields were also recorded, with both fields treated as equivalent.

The largest category represented was STEM engagement (65 articles or 30.52% of sample as either the primary or secondary field), followed by science communication practice (62 or 29.11%; **Figure 6**). Science communication theory was not as well represented, comprising only six articles (or 2.82%). Science education across all life stages was fairly equally represented in the sample with higher education (23 or 10.80%), secondary (25 or 11.74%), and primary and early childhood education (22 or 10.33%).

Articles with a clear single field were most common in the sample, with four of the five most frequent field codes having no secondary field (**Table 3**). Science communication practice (45 or 21.13%) was the most commonly occurring field code, followed by STEM workforce characteristics (27 or 12.68%), STEM engagement (15 or 7.04%), and Science education (HE) (12 or 5.63%; **Table 3**). The third most common combination of fields did have both primary and secondary codes - STEM engagement and identity work (18 or 8.45%). Most field code combinations were represented fewer than five times in the sample, with 18 of the 42 combinations only represented once.

DISCUSSION

This paper aimed to provide baseline evidence of how science communication has incorporated equity, inclusion and diversity in research and practice over the last 40 years. The systematic map process found that the attention paid to equity, diversity and inclusion matters has dramatically increased, with around 63% of

TABLE 3 | Fields of sample articles and their frequency (*n* = 213).

	No secondary field	Taxonomy	Astronomy, astrophysics and planetary science	Geoscience	Entomology	Environmental science	Medicine	Chemistry	STEM engagement	Identity work	STEM workforce characteristics	Science policy	Science communication theory	Science communication practice	Professional development	Science education (PS)	Science education (HS)	Science education (HE)
Science education (HE)	12			1			1		5	1	2		1					
Science education (HS)	9							1	9	3						3		
Science education (PS)	3								8	7				1				
Professional development	4										3		1					
Sci comm practice	45	2	1		1				4	3	3							
Sci comm theory	2																	
Science policy	2											1						
STEM workforce characteristics	27			1					2	1								
Identity work	4								18									
STEM engagement	15		1	1		1												
Chemistry																		
Medicine																		
Environmental science																		
Entomology																		
Geoscience																		
Astronomy, astrophysics and planetary science																		
Taxonomy																		

Primary and secondary fields are considered equivalent.

all articles published within the last 5 years. This is consistent with the timeline of the growing disciplinary awareness of the relationship between science communication and social inclusion assisted by the 13th Public Communication of Science and Technology Conference (Massarani and Merzagora, 2014). Certainly the dominant science communication academic journals are publishing articles about equity, diversity and inclusion. The Journal of Science Communication (JCOM) has been the most prolific publisher, although the recent (2020) research topic of "Inclusive Science Communication" in Frontiers of Communication could signal a further increase in focus of work in this area. Perhaps unsurprisingly, the majority of journals who publish articles with an intentional focus on articles related to equity, diversity and inclusion were education based, with articles concerning education at any stage, combined, the largest field represented. Arguably, classrooms create microcosms where differences created through circumstances beyond individual control can be seen in stark relief. This has long been recognised in teaching and requires an integrated inclusive approach which bridges both discipline and pedagogy (Stinken-Rösner et al., 2020). Perhaps there are lessons to be learned for science communication academics and practitioners from within the science education space.

Similar to the findings of Gerber et al. (2020), we found that papers from North America (especially the US) dominated our sample. Although likely a consequence of using only English language papers, this finding is consistent with previous studies showing the typical geography of scholarly work on equity and inclusion (Irwin, 2014) and reinforces the representation of science communication being predominantly white and Western (Guenther and Joubert, 2017; Canfield and Menezes, 2020). It may also influence the idea of who is considered to be minioritised and where. For example, in the US, Asian Americans may be considered an under-represented minority in STEM and the focus of science communication initiatives. But what of Asian science communication practitioners and researchers from other Asian nations? Although our study did find articles from Asian studies of science communication research and practice (e.g. Hopton and Walton, 2019; Ikkatai et al., 2019), and articles evaluating or describing activities in other countries, the authors tended to be those from the global north, not those from the country of study. As researchers, we could do better within our own practice. We echo previous studies which argue that researchers should make conscious and concerted efforts to increase the diversity of their collaborators, particularly in global or multinational studies where local people should make up at least part of the authoring team (e.g. Stefanoudis et al., 2021).

While most papers in our sample had excellent intentions and recognise the business and moral cases for diversity, equity and inclusion, the systematic map produced does not show a coherent and comprehensive body of work. This is likely a result of the disconnectedness of much of sample literature. Many articles in our sample were "one off"; single papers appearing in a broad catalogue of journals without a strong theoretical grounding consistently drawn from science communication literature. This perhaps also indicates that as a discipline, we do not yet have this strong evidence base. The findings of this mapping exercise suggest this could be the case. For example, the lack of guidance or evidence of best practice was evident in papers targeting implementers – those in the position to either advocate for, facilitate or implement more inclusive practice or policies. The papers aimed at this audience tended to be reviews and recommendations; very few were based on evaluations which specifically measured outcomes and impacts. Describing projects without sharing data about what works – rather than what simply sounds good – and what needs improving holds back the whole field and stymies attempts at reform (McKinnon, 2020).

The articles collected in this study show a disproportionate focus on girls and women. Although gender may be a visible characteristic, it is far from the only one which requires attention in the pursuit of equity, diversity and inclusion, and focusing solely on gender will not be enough to create the type of meaningful social and systemic changes needed. A Western, middle class, able bodied woman in biology would have a very different experience to a woman of colour, who is an immigrant, has a disability and works in engineering, for example. Focusing purely on gender would fail to identify and subsequently address these differences. There are small pockets of activity which recognise this, with some of the collected articles looking at populations with multiple factors such as gender, cultural background and socioeconomic status. It is this kind of intersectional approach which is necessary if we wish to develop systems, structures, policies and programs which are truly inclusive of the communities we serve (Thomas et al., 2021). Yet the results found in this study show that these kinds of studies are not yet common. In addition, minoritised groups, such as those with disabilities or from different cultural backgrounds, appear to also be overlooked in terms of research focus, appearing as the target audiences of a very small number of papers in our sample. While there is obviously scope for more work to be done with these communities, it is important to reflect on who is bearing the burden of research. Ashley (2020) comments on research fatigue, for example when minoritised communities don't see their contributions as having an effect, or are harmed through poorly designed projects. This could be, for instance, through unforeseen time or financial costs/commitments to be able to participate. Research fatigue has the potential to make communities reluctant to continue participating in studies, or from volunteering to participate in similar activities in the future. We believe this is an apt reminder of the importance for inclusion, equity and diversity interventions in science communication to be not just well-intentioned, but well-considered in their design, delivery and evaluation.

After science education, most of the papers in our sample were focused on STEM engagement and science communication practice, with theoretical work considering new models or frames for equity, diversity and inclusion in science communication somewhat lacking. Papers contributing to the development of science communication theory comprised under 3% of the entire sample. This may be related to the criteria of our search, with some known examples of this literature falling outside our inclusion criteria, such as books (e.g. Dawson, 2019) or reports (e.g. Canfield and Menezes, 2020; YESTEM

Project UK Team, 2020). This remains a gap that future research incorporating a broader range of sources could explore. It potentially also highlights an area where science communication researchers and practitioners could collaborate to make meaningful gains in developing an evidence base of what inclusive science communication is, does and for whom. Or even ascertaining if we are defining diversity, equity and inclusion in consistent ways across the discipline. This requires an integrated process of critical reflection at each stage of an intervention (Dawson, 2019). Some of this work is already in progress as seen in the YESTEM Equity Compass (YESTEM Project UK Team, 2020), an example of a practitioner-tested tool to guide reflection and reflexive practice, where reflection and action are interconnected (Salmon et al., 2017). As a discipline, we can do more, not only with our practice and research but also the communities we serve.

CONCLUSION

Forty years of literature shows that attention to equity, diversity and inclusion in science communication is entering a period of heightened awareness for researchers and practitioners alike. Yet this increased attention is not equitably distributed across historically under-served and minoritised audiences and does not go far enough to catalyse the societal, institutional and systemic changes required to create inclusive science communication theory and practice. Our results show that as a discipline, despite being aware of the white, Western, ableist and patriarchal nature of science communication (Canfield and Menezes, 2020), our theory and practice to date still largely reinforce these characteristics. Inclusive science communication must be intentional in its focus on under-served and minoritised communities, working *with* them as well as *for* them in both programs and in the development of theory. A robust evidence base of what constitutes best practice, for whom and how is vital if science communication - in theory and practice - wants to meaningfully fulfil its role in society, for all society members. Without a concerted focus on generating evidence and tracking progress, we will continue to tinker ineffectually at the edges.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

Both authors contributed equally to this work.

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