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Crossing boundaries between research and practitioner communities: The role of research use and cross-community journal authorship

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Abstract

This study pursued two major objectives. The first was to use bibliometric techniques to examine bidirectionality in the relationship between teachers and researchers, as indicated by collaborative authorship among these communities. The second was to explore more deeply knowledge mobilization to classrooms by documenting the extent to which research is cited in science education practitioner journals (SEPJ). Specifically, we examined: (a) the frequency of collaboration between researchers and practitioners in the writing of journal articles for both practitioner-focused and academic journals in science education, and (b) the extent to which authors of articles in practitioner-focused journals drew on academic research to support their advocacy for and/or description of science education programs, policies, or practices. Findings indicate that writing collaborations among academic researchers and practitioners are relatively infrequent, even on practitioner-focused articles. Also, articles in SEPJs more often cite books and other resources over academic journals, even those academic

journals focused on informing science education teaching and learning. Recommendations include providing open access to published research, development of research summaries for lay audiences, and incentivizing practitioners to engage in research and writing. This study explores only one mechanism by which knowledge can be mobilized to classrooms and only one type of dissemination product (i.e., journal articles) upon which researchers and practitioners can collaborate. Additional limitations are noted including the applicability of the findings only to the specific journals and timeframes analyzed.

KEYWORDS

academic research impact, citation analysis, knowledge mobilization, research mobilization, researcher–practitioner partnerships

Despite calls for better alignment between research and practice in education, the disconnect between educational researchers and practitioner communities persists (Penuel et al., 2015). Over the decades, scholars and policymakers began initiatives and published extensively on translating research to practice. For instance, the Education Sciences Reform Act of 2002 started the Institute of Education Sciences (IES: Institute of Education Sciences, 2022a). The IES promotes the design and implementation of reform-based programs and practices that are based on educational research (Whitehurst, 2003). Scholars, such as Constas and Sternberg (2006), worked on edited volumes focusing on a "collective effort to translate theory and research into educational practice (p. xii)" with contributions from authors with many years of experience in reducing the gap between the two communities. Additionally, from 2005 to 2010, Robert Yager and the National Science Teachers Association (NSTA, 2022a), via NSTA Press (NSTA, 2022b), published seven volumes in their "Exemplary Science" monograph series to promote research-based practices for practitioners to improve science teaching. These efforts were critical to increasing the impact of research on practice but have inherent limitations (Penuel et al., 2015).

One of the underlying problems with translation methods is the difference in language utilized by researchers and practitioners. It is uncontroversial to point out that academic research articles often contain concepts and research/academic-specific language and terms (often referred to as "jargon") that practitioners may not understand. If the goal of mobilizing research knowledge is to communicate findings with practitioners and policymakers, the use of such "jargon" might well lead practitioners to discontinue their reading or to misinterpret the meanings and ideas suggested by researchers (Dynarski & Kisker, 2014). Another problem with the current translation methods is the inaccurate or insufficient description of research findings and implications across settings (Penuel et al., 2015). Many research articles present findings and implications that apply strongly to the local context without exerting parallel effort toward describing the applicability of those findings/implications to other contexts. Consequently, practitioners may assume the findings do not directly relate to their individual challenges. Beyond this, current translation theories/methods are based on the premise of unidirectional relationships (i.e., from

researcher to practitioner), a concept that may disenfranchise practitioners and undervalue their potential contributions. Some of these issues led teacher education scholars and curriculum developers toward the development of collaborative research-practice partnerships where the relationship between researchers and practitioners is bidirectional or "reciprocal" (Easton, 2013, p. 18). Similarly, in the spirit of bidirectional flow of knowledge between researchers and practitioners, we have generally opted in this paper to use the term research/knowledge "mobilization"[1] over research/knowledge "translation."

The following sections will provide conceptual framing for bidirectional collaboration among researchers and practitioners. As one indicator of bi-directional collaboration in science education, this study explores the frequency of collaboration between practitioners and researchers in writing both practitioner-focused and academic research articles. As a deeper analysis of practitioner-focused articles, we also explore through bibliometric (citation) analysis the extent to which research is leveraged in supporting proposed instructional practices, and the influence of academic (e.g., university-affiliated) authors on that outcome. With regard to the latter, our attention to practitioner-focused journal articles stems from their assumed (but untested) role in facilitating a synergistic relationship between research and practice. This study provides a unique contribution to the nascent literature base by examining the role of collaborative writing in facilitating bi-directional relationships between practitioners and researchers.

1 | BACKGROUND

1.1 | Bi-directional relationships between researchers and practitioners

Documented challenges to research translation have encouraged educational research scholars to reconceptualize the research-to-practice relationship. In these recent conceptualizations, production and use of research are considered reciprocal or "bidirectional" in nature (e.g., Farley-Ripple et al., 2018; Penuel et al., 2015). During the American Educational Research Association's presidential address in 2012, Arnetha Ball provided a review of research-to-practice models that aim to close the gap between research and practice. She highlighted four common models. Two of these suggest a unidirectional approach. First is the "Research Diffusion Development Model" (RDDM), which relies on a hierarchical perspective of producing knowledge for practitioners. The RDDM begins with a researcher who conducts basic theoretical or conceptual research in the field of education. Another researcher, with more focus on practitioner-oriented work, translates the basic research to mediators (e.g., teacher educator, curriculum coordinator). The mediators then translate this work for practitioners. Second is the "Evidence-Based Practice Model" (EBPM). The EBPM researcher mostly focuses on empirical evidence drawn from experimental studies. Similar to the RDDM, the EBPM relies on a mediator to communicate the findings to practitioners.[2] These two models rely on a unidirectional relationship where the knowledge flows only from the researcher to the practitioner.

Ball (2012) describes the additional two models as reflecting a bidirectional relationship between the researcher and the practitioner. The bidirectional models were derived from the theoretical framework for communities of practice (Wenger, 1999). A community of practice is defined as "a group of people who mutually engage in a joint endeavor and share a repertoire of resources" (Wenger, 1999, p. 73). The communities of practice are formed when members

(a) share a domain of interest and are actively committed to that domain; (b) engage in joint activities (formal or informal) in pursuit of improvement; and (c) develop a shared repertoire of resources (e.g., tools and experiences) that become defined as common practices. When researchers, practitioners, and other stakeholders (e.g., policymakers) participate in a shared community space, they co-construct meaning and revise personal identities (Wenger, 1999) such that there is an interaction whereby practitioners can influence the interpretation of research findings and the pedagogical advice put forward by researchers influences the reflection and perspectives on practice held by the practitioners.

Even though there are overlapping commonalities, researchers and practitioners differ in numerous ways, such as how they frame the problems of practice and instructional design solutions (Reiser et al., 2000) and the pace at which they need to act on solutions (Coburn et al., 2013). Thus, there are ongoing debates about approaching researchers and practitioners as two separate communities (Neumann et al., 2019), a view made especially problematic given that many researchers are former $K{-}12$ teachers and many teachers of those grades have done graduate work of some sort that, at the very least, has introduced them to research findings particular to their fields (we also acknowledge that a smaller group have participated in research projects where their class or school was studied by a researcher). The overlaps and differences between the communities suggest that researchers should utilize the two-communities approach to look closer at the differences and explore situations where those differences fade (Farley-Ripple et al., 2018). Another model that highlights research to practice is the "Knowledge Communities Model" (Craig, 1995). In this model, researchers, practitioners, policymakers, and mediators maintain separate roles. However, the separate entities engage in a partnership to regularly exchange knowledge and experience, which is the foundation of a bidirectional relationship.

Advocacy for bidirectional approaches has been echoed in more recent thought such as the framework proposed by Farley-Ripple et al. (2018), where they suggest an inclusive approach to narrowing the gap between research and practice that draws on the expertise of researchers and practitioners. Specifically, they suggest improving the depth of evidence used in the educational decision-making process; providing better links between the searching done by practitioners (for evidence) and the dissemination efforts of researchers; facilitating "interpretation" of research findings and context; engaging in increased participation from multiple communities in the research production and use process; considering the decision stage that includes a plan for how researchers anticipate the applied use of their findings during decision-making (which may very well influence the design of their research); and better understanding the frequency of use and production of research (i.e., How often do practitioners use research in a conscious fashion, and how frequently do researchers plan their research taking the interests of practitioners into account?) (Farley-Ripple et al., 2018).

In reviewing this literature on research to practice models in educational contexts, we note two common themes. The first is the value of knowledge transfer between practitioner and researcher communities, where the input from practitioners is often around students' needs and the nature of authentic classroom contexts. The second is the need for researchers to provide accessible descriptions of findings, the context(s) in which they were obtained, and the applicability of those findings across a range of contexts.

Finally, to assist in framing this study, we introduce the notion of "boundary crossings." Acknowledging the cultural, professional, and organizational differences between researchers and practitioners, some scholars use the term boundary crossings to refer to researchers navigating practitioner's communities (Penuel et al., 2015). The idea of boundary crossing comes

from Cultural-Historical Activity Theory (Engeström, 1999), where subjects engage in activities shaped by a community, the tools used by the community, the division of labor among community members, and the rules/norms established by community members over time. When the community members of one activity system interact with or transition into activity systems of other communities, these members cross boundaries and consequently "face the challenge of negotiating and combining ingredients from different contexts to achieve hybrid situations" (Engeström et al., 1995, p. 319). In a research-to-practice context, boundary crossings can happen, for example, if a university researcher co-teaches a science lesson with a middle school teacher or when a middle school teacher participates in a research conference. However, in addition to these two intuitive examples, we describe how additional boundary crossing opportunities may emerge when researchers and practitioners engage in collaborative journal article writing for either academic or practitioner journals. In both instances, we refer to the bidirectionality emerging from communities of practice (see above). Since practitioners and researchers each have their own experiences and practices that reflect their individual communities, the writing approach for each often reflects the interests and practices of one community and not the other. As such, the writing of either type of journal article represents a boundary crossing between the two communities of practice. We note here that there are instances when boundary crossing via journal authorship does not involve collaborative, bi-directional work between practitioners and researchers, where meanings and understandings are negotiated between participants (e.g., a researcher as a sole author of a practitioner-focused article).

1.2 | Journal article authorship as a tool for bi-directional interaction

In this study, we consider the role of journal articles as "objects" acting as boundaries which when crossed by either (or both) academics or practitioners can cross-fertilize communities and facilitate the genuine researcher–practitioner collaborations desired in the field (e.g., Adamson & Walker, 2011). Boundary objects are tools or mediating artifacts at the boundary crossings that can serve to bridge two intersecting practices (Akkerman & Bakker, 2011; Star, 1989; Star & Griesemer, 1989). We assert that when researchers and practitioners, alone or in collaboration, author articles outside of their primary community, these writing efforts can serve as boundary crossings that can represent worthwhile bi-directional forays into each other's communities. With regard to practitioners authoring or co-authoring research, we echo the sentiments of a now 30-year movement around teachers' involvement in research in which the practitioner's invaluable and tacit lens of relevance is acknowledged (Ancess et al., 2007; Cochran-Smith & Lytle, 1999; Runesson Kempe, 2019; Thorsten, 2017). Further, we join researchers in recognizing the opportunity research authorship provides in allowing practitioners to exercise their democratic rights in knowledge generation (e.g., Reis-Jorge, 2007). In the case of researchers publishing in practitioner journals, we suggest that simply documenting the existence of such boundary crossing publications is not sufficient. To fully understand the potential contribution of practitioners and research publications in synergizing research and practice, we must assess the extent to which science education practitioner journal (SEPJ) publications reference academic research journals (ARJs) to support claims about programs or practices for teachers and students. For the purpose of this article, our reference to ARJs is to those specifically in the field of science education and not to ARJs in general.

1.3 | Relevant journal policies

As additional framing for the results presented in this article, it is important to document any explicit restrictions in the policies of the SEPJs and science education ARJs we studied with respect to who was allowed to contribute as authors. With regard to authorship in the top research journals in science education (i.e., *International Journal of Science Education*, the *Journal of Research in Science Teaching*, and *Science Education*), journal policies indicate no restrictions on who can submit manuscripts. More specifically, practitioner authors (i.e., practicing teachers) are neither discouraged nor encouraged to submit manuscripts (IJSE, 2022; JRST, 2022a; Science Education, 2022). Similarly, the top three practitioner-focused NSTA journals with a focus on *K*–12 science education, *Science and Children*, *Science Scope*, *and Science Teacher* have no restrictions on who can author manuscripts and neither encourage nor discourage submissions from researchers (e.g., NSTA, 2022c), as is also the case for the practitioner journal *Science Activities* published by Taylor & Francis (see "Instructions for Authors"; Science Activities, 2022).

Concerning the use of research from ARJs within the three NSTA journals mentioned above, all of them strongly encourage citation of research, stating in their guidelines that feature articles should include, "*support for claims made in the manuscript, including research citations and personal anecdotal evidence*" (e.g., NSTA, 2022c). Likewise, ARJs in science education espouse at least a partial focus on informing practice. For example, the Aims and Scope for the *Journal of Research in Science Teaching* indicate that the journal "...publishes reports for science education researchers and practitioners on issues of science teaching and learning and science education policy" (JRST, 2022a). Moreover, the guidelines for authors state that, "... It is expected that you establish the importance of the study for science teaching and learning ..." (JRST, 2022b). Similarly, the ARJ *Science Education* states, "Science Education publishes original articles on the latest issues and trends occurring internationally in science curriculum, instruction, learning, policy and preparation of science teachers with the aim to advance our knowledge of science education theory and practice." Author guidelines for articles in the Learning category elaborate, "Studies examining the relationship of learning to teaching, the science knowledge and practices, the learners themselves, and the contexts (social, political, physical, ideological, institutional, epistemological, and cultural) are similarly welcome" (Science Education, 2022). Finally, the *International Journal of Science Education* (IJSE) sends what we saw as the strongest message to authors, in its Aims and Scope, about the desired impact on teaching practice, stating:

> The *International Journal of Science Education* is firmly established as an authoritative voice in the world of science education. IJSE publishes scholarly papers that focus on the teaching and learning of science in school settings ranging from early childhood to university education. It bridges the gap between research and practice, providing information, ideas and opinion.
>
> (IJSE, 2022)

The IJSE Aims and Scope reaffirm their commitment to supporting teaching and learning through research by stating: "Special emphasis is placed on applicable research relevant to educational practice, guided by educational realities in systems, schools, colleges, and universities" (IJSE, 2022). These statements seem to imply a desire by the ARJ publications and the SEPJs to establish an effective pathway between research and practice.

1.4 | The importance of research use in practitioner journals

Recent US legislation requires school districts to adopt evidence/research-based practices or programs for students (e.g., Education Sciences Reform Act [ESRA, 2002; Every Students Success Act [ESSA, 2016). Often, the selection of effective programs or practices is a task shared by school district leadership and classroom teachers. There are a number of mechanisms by which teachers and district decision-makers can gather information to inform such programmatic decisions. For science educators, these include professional meetings, reviews of curriculum programs for research-based features (e.g., EQuIP Rubric for Science: Achieve, 2022), reviews of impact studies (e.g., What Works Clearinghouse: Institute of Education Sciences, 2022b), and through practitioner-focused publications, such as those published by the NSTA. One goal of SEPJ articles is to demonstrate that the practices they describe are based on research and, hence, worth adopting. The focus on practitioner-focused publications (i.e., SEPJs) in this paper acknowledges the role that they can play in informing programmatic decisions at the classroom level, as well as higher levels of the education system.

1.5 | Prior studies of research use and authorship in practitioner journals

Historically, co-authorship among researchers and practitioners and the use of science education research in SEPJ articles has garnered little attention. We found no published studies of practitioner authorship in science education research journals, although we acknowledge that some may now exist. With regard to co-authorship, we highlight the findings of one notable study (Entress, 2020) that explored collaboration between academics and practitioners in writing articles for practitioner journals, finding low rates of collaboration and only modest growth since 1940.

With respect to research use in practitioner journals, Hand et al. (2010) examined the consistency between how classroom science literacy strategies were supported by research in practitioner journals, and how the strategies were supported in the research literature. They found stark inconsistencies that raise concerns for the bi-directionality of communication between researcher and practitioner communities. Related subsequent work by Jagger and Yore (2012) yielded similar results, reporting that science literacy recommendations in NSTA's SEPJs had little empirical support. Aydın et al. (2013) took a topic-specific approach, focusing on the extent to which NSTA SEPJ articles provide research-based model activities. They reported that many SEPJ articles lacked a strong theoretical backing.

1.6 | Study purpose and research questions

It is widely acknowledged that collaboration, in some fashion, among educators and researchers is critical to closing the gap between research and practice. However, there is still a limited understanding of the development of such collaborations and the implementation of new knowledge in classroom practice. In this paper, we focus on collaborative journal article writing as one indicator of bi-directional relationships between practitioners and researchers and a critical strategy in efforts to closing the gap between research and practice.

Our *first goal* was to broaden the scope of prior research by examining the frequency of boundary crossing journal authorship in both ARJ and SEPJ articles. Further, as researchers, we sought to explore more deeply the role of our community in the research grounding of SEPJ articles. Based on the premise that research grounding is one benefit that a researcher/academic author might likely contribute to a SEPJ article, our *second goal* was to examine the frequency in which research is cited in SEPJ articles and the influence of academic authors (and other factors) on that frequency.

These goals required two lines of inquiry. First, we examined the frequency of bi-directional interactions between researcher and practitioner communities by documenting the frequency with which practitioners publish in science education ARJs and the frequency with which researchers and practitioners publish in SEPJs, where both are considered desirable boundary crossings. Second, we examined the extent to which SEPJ article authors drew on research to support their advocacy for various programs or practices. Specifically, we explored citation rates in SEPJs for selected types of resources, including citation rates of the leading research journals in science education, while disaggregating these results by author (e.g., researcher/academic vs. non-academic) and article types.

While this study focused on citation rates of journal articles as an indication of empirical justification for instructional strategies and practices discussed in SEPJ articles, we note here that citing books can also provide such justification as some books draw upon and synthesize research from peer-reviewed journals (e.g., A Framework for *K*–12 Science Education) while also noting that books may not provide details about the academic studies including methodologies, data, or relevant context that may be useful for implementing their findings (see Grinnell, 2009). As such, we acknowledge that for SEPJ articles that cite journal articles and books, the journal citation rates can be considered a lower bound on the frequency with which SEPJ articles provide research-based justifications for the practices they describe.

This study employed bibliometric research techniques to address the following research questions, which correspond to our two goals above:

1. How frequently do boundary-crossing articles occur in science education?
   a. How frequently are practitioners publishing articles in prominent ARJs in science education?
   b. How frequently are researchers/academics publishing articles in SEPJs?
2. What types of resources are cited in SEPJs and in what proportions?
   a. Among the research journal citations in SEPJs, what proportion of those citations are from the top research journals in science education?
   b. To what extent does SEPJ first author type (e.g., researcher/academic vs. practitioner) influence citation of research journals?
   c. To what extent does citation of research depend on the type (column vs. regular article) and purpose (e.g., provide information vs. describe activity) of the SEPJ article?

2 | METHODS

To address our research questions, we obtained and analyzed 5 years of bibliographic data from four SEPJs that are specifically oriented toward *K*–12 science teachers, and three highly ranked science education research journals. Please see Kubsch (2023) for access to the raw bibliometric data used in this study, as well as our analysis syntax.

2.1 | Data sources

For Research Question 1a, we examined the frequency of practitioner authorship and first authorship in three prominent research journals in science education: *International Journal of Science Education* (*IJSE*), *Journal of Research in Science Teaching* (*JRST*), and *Science Education* (*SE*). Articles published in 2013 through 2017 in these journals were eligible for inclusion. All articles in the inclusive years of these journals were screened for practitioner authorship. In total, across the five years of science education ARJ article publishing which we examined, 1189 articles were screened for practitioner authorship, 652 (55%) for IJSE, 283 (24%) for JRST, and 254 (21%) for SE. Proportions were similar across the five years (see Table 1).

For Research Question 1b, we considered three NSTA publications, *Science & Children* (S&C), *Science Scope* (SS), and *The Science Teacher* (TST), along with the non-NSTA practitioner journal *Science Activities* (SA). Collectively, *Science & Children*, *Science Scope*, and *The Science Teacher* are publications directed toward pre-college teachers (pre-K through Grade 5, Grades 6–8, and Grades 9–2, respectively). These journals include articles about science activities/strategies that are developed and tested by teachers (and others, such as researchers), peer-reviewed, and intended to help teachers teach in ways consistent with the *Framework for K–12 Science Education* (see NSTA, 2022c). Although now publishing six issues per volume, each NSTA journal in the years we analyzed published nine issues each year. *Science Activities* continues to publish four issues per year.

In terms of dissemination, NSTA reports that each of its journals has a circulation of at least 4500 readers (NSTA, 2022d, 2022e, 2022f). NSTA self-describes the readership of these journals including science educators, administrators, and curriculum planners across the United States and Canada. The exposure of these journals is expanded, domestically and internationally, through NSTA membership and online access; for instance, students in education programs can often access them through their universities and NSTA members have full access to at least one of the journals. Approximately 70% of the current subscribers to *Science & Children*, *Science Scope*, and *The Science Teacher* are affiliated with public *K*–12 schools. Only a portion, ranging from 15% to 20%, are affiliated with post-secondary schools, including 2- and 4-year schools, and graduate schools. For perspective, consider, of the nearly 7000 member subscribers to *The Science Teacher*, those self-identifying as "professor" and "scientist," 7.6% and 5.3%, respectively, are outnumbered by the 75.7% who hold teaching positions in *K*–12 schools

TABLE 1 Count and distribution of articles reviewed from prominent science education academic research journals.

	Year					
Journal	**2013**	**2014**	**2015**	**2016**	**2017**	**Total**
International Journal of Science Education	120	130	134	148	120	652 (55%)
Journal of Research in Science Teaching	51	51	65	63	53	283 (24%)
Science Education	47	55	55	47	50	254 (21%)
Total	218 (18%)	236 (20%)	254 (21%)	258 (22%)	225 (19%)	1189

Note: Column totals show proportions of articles collected from a specific year and row totals show the contributions from each journal.

(P. Lindeman, personal communication, January 25, 2021). *Science Activities*, published by Taylor and Francis, is an international, peer-reviewed journal from a major publisher that provides teachers and educators with classroom-tested projects, experiments, and curriculum ideas that promote scientific inquiry through active learning experiences.

For the sake of our analysis, an "article" was defined as a written piece that could be a column (unrefereed and recurring) or an unsolicited and refereed piece, provided it was geared toward understanding or engaging in classroom practice (as opposed to policy or science content pieces). In sum, data for questions 1b and 2 of the present study draw on 1500 individual entries (articles) that met the criteria for analysis from these SEPJs, averaging 300 entries per year. Contributions from each of the publications were generally consistent across all years. For 2013, a total of 317 journal entries were coded (S&C = 106, 33%; SS = 100, 32%; TST = 95, 30%; and SA = 16, 5%), and the proportions of entries from each publication were similar across the years we examined (Table 2).

2.2 | Coding

2.2.1 | Coding for Research Question 1a

To identify practitioner authors in science education ARJs, coders examined the biographic information of all article authors, identifying practitioner authors as those having a *K*–12 school district affiliation, regardless of position within the school district. For example, classroom teachers, principals, instructional specialists, and district-level personnel (e.g., curriculum coordinators) were all coded as practitioners. For the purposes of this coding scheme, non-practitioners were all other categories of researchers such as academics, consultants, or researchers working for non-profit or for-profit research organizations.

2.2.2 | Coding for Research Questions 1b and 2a–2c

In addition to the title and author of each SEPJ article, general identifying information including volume, issue, and publication was compiled for each entry. When available, the author's biographical information was collected and first authors were assigned to one of the following

TABLE 2 Count and distribution of articles reviewed from science education practitioner journals.

	Year					
Journal	**2013**	**2014**	**2015**	**2016**	**2017**	**Total**
Science & Children	106	105	105	100	112	528 (35%)
Science Scope	100	88	85	93	111	477 (32%)
The Science Teacher	95	86	87	85	78	431 (29%)
Science Activities	16	12	12	14	10	64 (4%)
Total	317 (21%)	291 (19%)	289(19%)	292 (19%)	311 (20%)	1500

Note: Column totals show proportions of articles collected from a specific year and row totals show the contributions from each journal.

categories: (a) preservice teacher, (b) classroom teacher, (c) education graduate student, (d) education graduate student AND classroom teacher, (e) education professor, (f) science graduate student, (g) science professor, and (h) "other" (e.g., administrators, principals, and consultants). Given the focus of the study, references included in the database were tabulated and categorized as (a) research journal articles, (b) web-based resources, (c) teacher journals, or (d) books (including book chapters) and reports.

Citations from journals were further examined to count the number of references to top-tier science education ARJs. Here, we focused on the *Journal of Research in Science Teaching* (JRST, impact factor: 4.832), *Science Education* (SciEd, impact factor: 4.593), *International Journal of Science Education* (IJSE, impact factor: 2.241), and *Research in Science Education* (RISE, impact factor: 5.439). Other journals cited were tabulated and identified separately. When coding the SEPJ articles, entries were each assigned an "article type"—which generally distinguished refereed articles from regular columns—and codes were generated and applied to all entries to characterize "article purpose." The purpose categories distinguished: (a) Classroom Practice (articles intended to help teachers improve their instructional practice or classroom environment); (b) Classroom Activity (articles focused on classroom science activities that often include resources such as table design, example questions, and discussions of implementation issues); and (c) Information-Based (articles that were neither (a) nor (b) but conveyed new information about science, science findings, or were related to science education). Note that some NSTA publications include other authored entries, such as editorials, opinion pieces, and book and product reviews, but these entries were excluded from our sampling as they were not related to our core interests.

Coding was completed by three science education faculty, some with the assistance of graduate students. One researcher led the development of the codes previously outlined, and the research team defined and clarified the coding criteria. Coding decisions and discrepancies were addressed through an iterative process involving regular meetings with all team members until all issues were resolved.

For all variables that required coding of authors exclusively as researchers or practitioners, we acknowledge that the researcher/practitioner distinction is imperfect and very much one that applies specifically to the role an author has at the time of publication of an article. Specifically, we understand that many education researchers are former practitioners (e.g., *K*–12 teachers), but whose role at the time of publication included formal and significant expectations for research productivity. Similarly, we understand that some current teaching practitioners also conduct research (e.g., action research) and may also be engaged in graduate study that includes formal research. Further, if a practitioner author is also a graduate student and uses their academic affiliation, their practitioner role could be masked, especially since the ARJ articles did not consistently include detailed author biographies.

2.3 | Analysis methods

For Research Question 1a, we tabulated the number and proportion of authors of science education ARJ articles who were coded as practitioners and disaggregated these results by journal and year. For Research Question 1b, we tabulated the frequency of authorship for practitioner and non-practitioner author types in the SEPJs of interest. Finally, for Research Questions 2a–2c, we tabulated the number and proportion of the various types of reference

resources that were cited in the SEPJs, and disaggregated those results by journal, journal prominence, first author type, and article type.

3 | RESULTS

3.1 | Research Question 1a

Table 3 illustrates the infrequency of practitioners publishing in science education ARJs, as a primary or secondary author. The number of instances of practitioner authorship (middle column of Table 3) includes first and non-first authorships. No journal has a practitioner author rate greater than 1.6%.

3.2 | Research Question 1b

Table 4 illustrates the predominant role that academics play in authoring SEPJ articles. Further, additional analyses indicate that 39% of articles in SEPJ are authored by solely academic teams, 37% of articles are authored by solely non-academic teams, and only 24% of articles are authored by teams in which academics and non-academics collaborate. This indicates clear room for growth in collaboration between academics and practitioners toward SEPJ writing efforts.

3.3 | Research Question 2a

Figure 1 shows that for all four SEPJs, books and reports have the largest proportion of citations. In *Science Activities*, ARJs (science education and other research journals) are cited more often than practitioner journals. In the other three SEPJs, the proportion of ARJs and practitioner journals cited is more similar. In all journals, except *Science & Children*, websites are also a substantial source for citations.

Looking more closely at the types of research journals that are cited, all publications present a similar picture with a majority of citations coming from journals other than the leading science education ARJs (Figure 2). The leading science education journals account for 26% of

TABLE 3 Number and percentage of science education ARJ articles authored by education practitioners.

Research journal	Number of articles with a practitioner author	Number of articles with a practitioner first author[a]
International Journal of Science Education	10/652 (1.5%)	2/652 (0.3%)
Journal of Research in Science Teaching	2/283 (0.7%)	0/283 (0.0%)
Science Education	4/254 (1.6%)	1/254 (0.3%)

Abbreviation: ARJ, academic research journal.
[a]This column is a subset of the one to the left of it.

TABLE 4 Number and percentage of SEPJ articles authored by various first author types.

Practitioner journal	Classroom teacher	Education graduate student	Education graduate student and classroom teacher	Education professor	Pre-service teacher	Science graduate student	Science professor	Other
Science & Children	111 (21%)	24 (5%)	3 (1%)	195 (37%)	2 (0%)	1 (0%)	18 (3%)	174 (33%)
Science Scope	114 (24%)	46 (10%)	4 (1%)	127 (27%)	0 (0%)	11 (2%)	82 (17%)	93 (19%)
Science Teacher	151 (35%)	18 (4%)	3 (1%)	96 (22%)	0 (0%)	5 (1%)	29 (7%)	129 (30%)
Science Activities	2 (3%)	1 (2%)	0 (0%)	42 (66%)	0 (0%)	3 (5%)	11 (17%)	5 (8%)

Abbreviation: SEPJ, science education practitioner journal.

journal citations in *The Science Teacher*, 16% of citations in *Science Activities*, 24% of citations in *Science Scope*, and 18% of citations in *Science & Children* (all values rounded).

When we examine citation of science education ARJs as a proportion of total citations (i.e., including all cited sources, journals, and otherwise), we see that *JRST* was the most cited science education ARJ (1.9% of all cited sources), followed by *Science Education* (1.2% of all cited sources), *IJSE* (1.0% of all cited sources), and finally *RISE* (0.02% of all cited sources). This order broadly reflects the impact factors of the journals with an exception for *RISE* and *IJSE*, where the impact factor of *RISE* is higher than the impact factor of *IJSE*. While some differences between SEPJ publications exist, science education research journals are rarely cited in SEPJs, accounting for less than 5% of all citations.

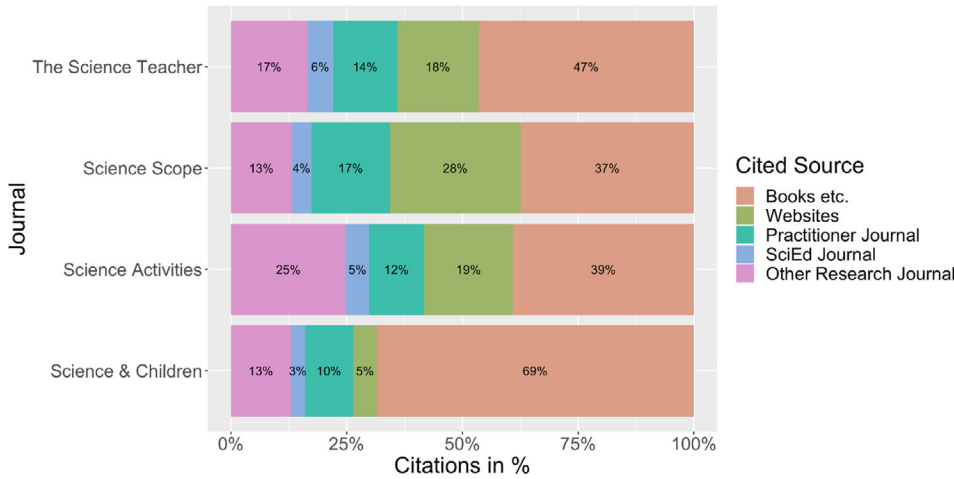

FIGURE 1 Distribution of cited resources across SEPJs.

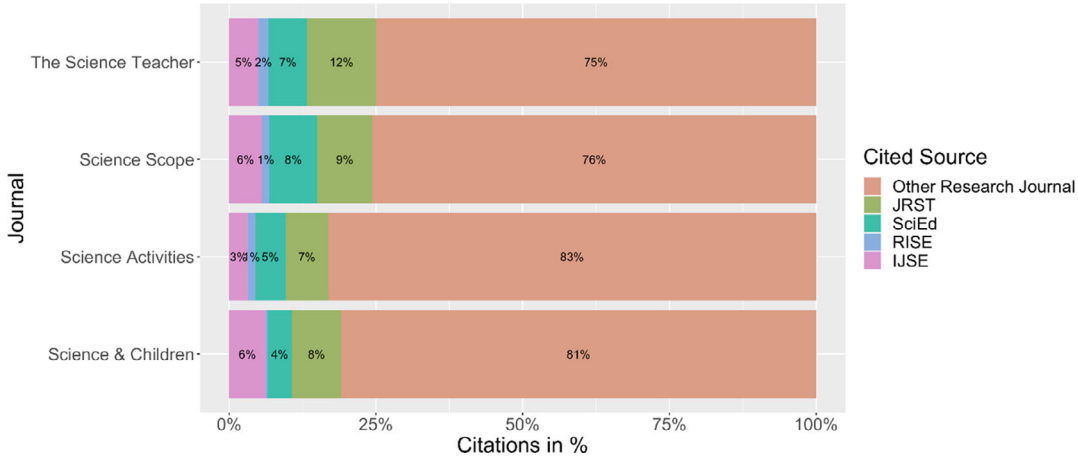

FIGURE 2 Distribution of cited journal resources across SEPJs.

3.4 | Research Question 2b

For this question, we investigated the kinds of resources different authors cited in their SEPJ articles. Figure 3 shows that across the range of SEPJ authors types, books remain the most widely cited resource. Even education professors and education graduate students rarely cite science education ARJs (13% and 15% of the resources they cite come from science education ARJs, respectively). Examining journal citations in particular, Figure 4 reveals that *JRST* and *Science Education* are cited the most while *IJSE* and *RISE* are usually cited less frequently. In sum, the low citation rate of the leading science education research journals is relatively stable across different types of authors.

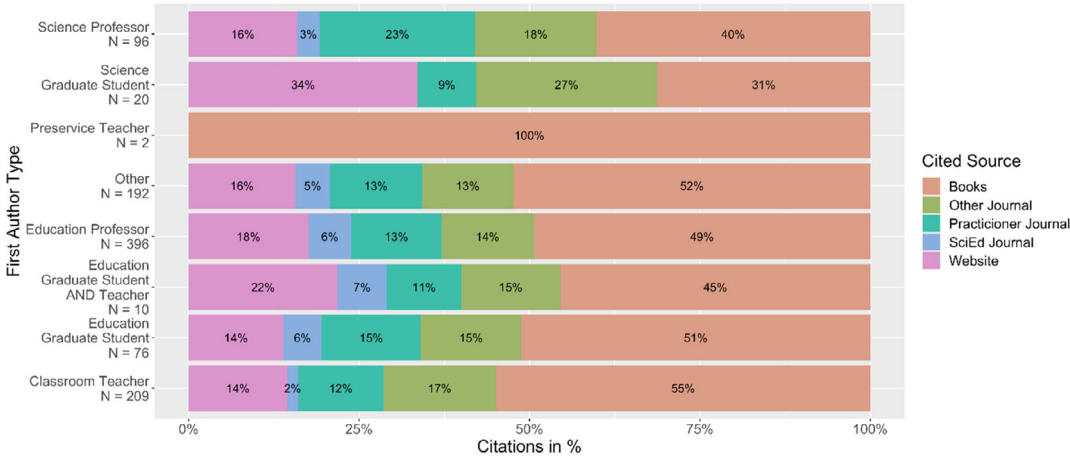

FIGURE 3 Proportion of cited resources in SEPJ articles by first author type. SEPJ, science education practitioner journal.

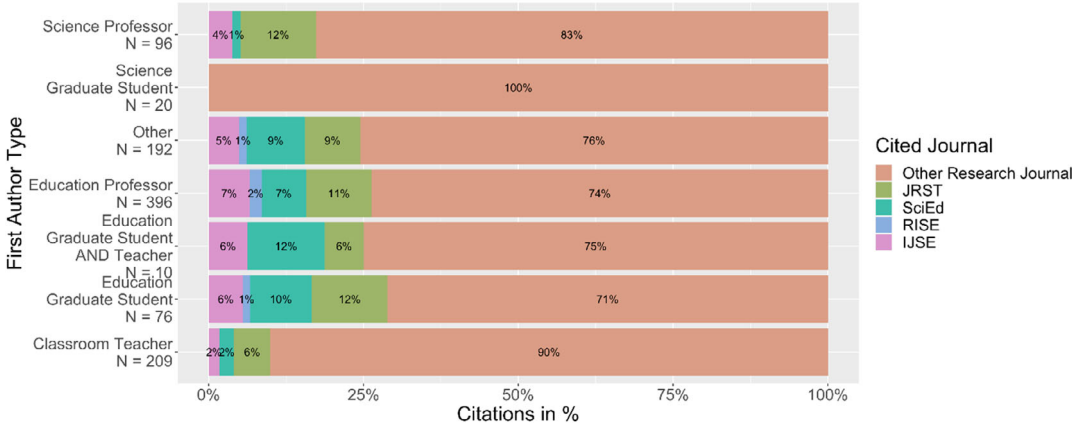

FIGURE 4 Proportion of cited ARJs by first author type. ARJ, academic research journal.

3.5 | Research Question 2c

Finally, we analyzed the extent to which SEPJ article type (refereed article vs. unrefereed column) and purpose influenced what was cited in SEPJs. Figure 5 (top) shows that for refereed SEPJ articles, the proportions of cited sources are relatively similar across article purposes. In contrast, Figure 5 (bottom) indicates that SEPJ columns with the purpose of conveying information (only) have a much larger proportion of website citations than columns that describe classroom activities or classroom practices. Further, the proportion of ARJ citations (for science education ARJs and other ARJs) in SEPJ columns is greatly diminished in comparison to SEPJ articles, independent of purpose. A respective ANOVA supports this conclusion as the difference in science education ARJ citations across article purposes was not significant ($F(2, 1495) = 2.48$, $p > 0.05$), but there was a statistically significant difference in science education ARJ citations across article types, column versus article ($F(1, 1495) = 56.63$, $p < 0.001$).

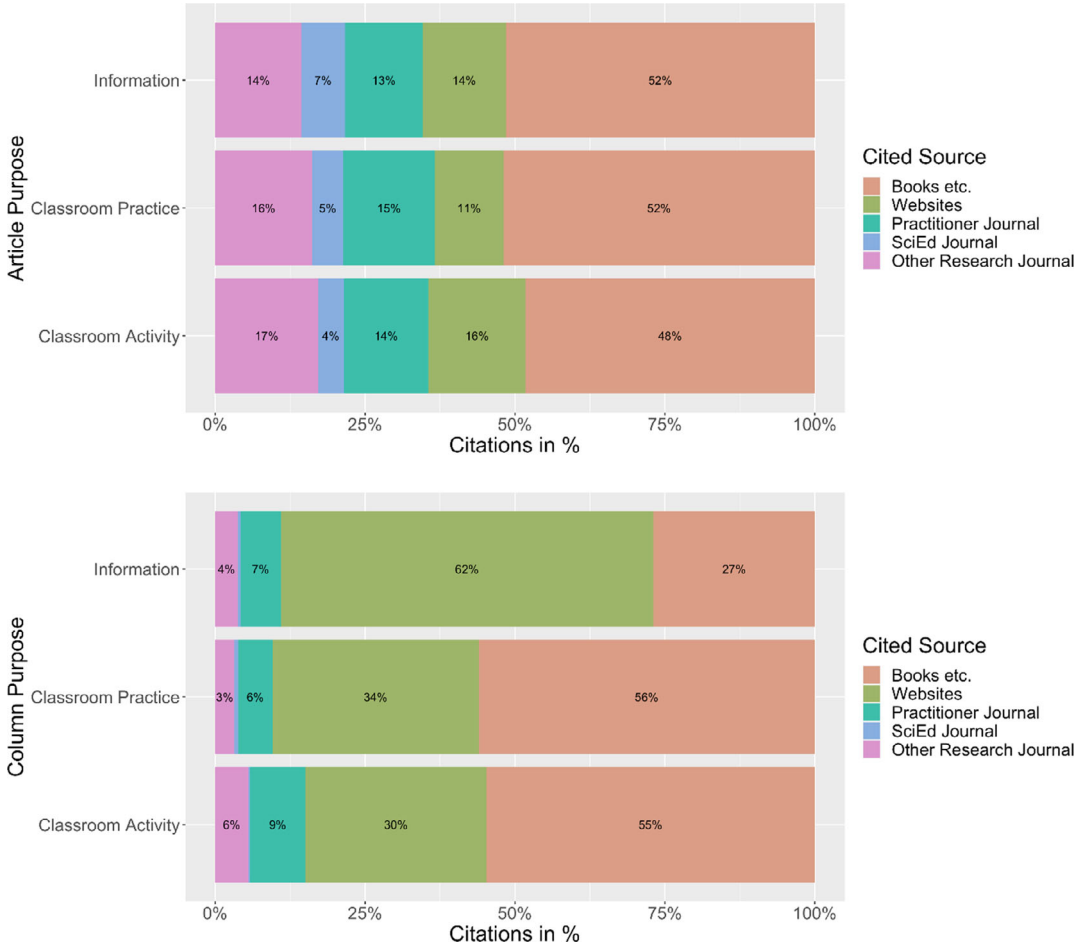

FIGURE 5 Distribution of cited resources in SEPJs across article type and purpose.

4 | DISCUSSION

Hand et al. (2010) recommended that we consider new models for how researchers and practitioners might interact and collaborate on research and scholarship and how such models might facilitate research use by practitioners. Toward this charge, the current study examined the extent to which researchers and practitioners are collaborating on journal authoring efforts as well as the citation of research in practitioner journals. Regarding the former, we observed that bidirectional interaction of the science education research and practitioner communities is not happening frequently via boundary crossing authorship of research or practitioner-focused journal articles.

More specifically, instances of practitioners as lead or co-authors of research journal articles are very infrequent during the years reviewed in this study, suggesting lack of practitioner-researcher collaboration on published research studies in science education. Perhaps this provides some evidence that the teacher-as-researcher movement discussed in Cochran-Smith and Lytle (1999) has not fully achieved its intended outcomes, at least in terms of teacher authorship in recent science education journals. Perhaps this is due, in part, to some of the negative perceptions of academic research that Labaree (2003) identifies as making it difficult to encourage and enculturate teachers to engage in research. In noting this we acknowledge that currently there are few extrinsic or intrinsic incentives for practitioners to publish in ARJs. However, if we as a science education community truly value a practitioner's lens on conducting and publishing research, then we must put additional thought and effort into incentivizing and otherwise encouraging such work by practitioners. We recommend possible incentives in a later section that describes long term considerations.

In terms of SEPJ authorship, the types/affiliations of authors are more varied and include practitioners more often than in ARJs. However, academics still author SEPJ articles approximately twice as often as practitioners. This latter finding is not inherently concerning but remarkable given what Stevens (2004) noted about incentives for academics to publish in practitioner journals. While it is the case that some education colleges/departments highly value or even require publication in practitioner-focused journals, others view publications in practitioner journals as less scholarly, carrying less weight toward promotion and tenure. In the latter case, this penalty could result in important research findings never being mobilized to inform the work of teachers and administrators. Despite the inhibiting factors that are faced by some academics, perhaps the prevalence of academic authorship in practitioner journals is more about the lack of time or incentives for practitioners to publish; resulting in fewer journal submissions from the practitioner community. Authorship of SEPJ articles by academics is certainly something to be embraced, provided that it does not crowd out such opportunities for non-academic authors. Strategies that encourage collaboration among academics and practitioners on practitioner-focused articles could balance the authorship perspectives of these articles, as well as increase the reach of research findings into classrooms.

Moreover, we examined the role of peer-reviewed research in supporting the recommendations and student activities described in practitioner articles. We observed that SEPJ articles cite books and websites most often, with few peer-reviewed journal articles cited, and even fewer citations from the most highly regarded peer-reviewed science education research journals. Interestingly, this pattern was similar regardless of whether the author was a practitioner or an academic or based on the purpose of the article (as we have defined them above). Despite the call in the SEPJ guidelines for authors to include research citations, our study showed that the articles are falling considerably short of this goal for the time period and specific journals we

studied. The purpose of this assessment was not to pass judgment on these articles as not being research-based, but more that they often provide little overt evidence of how the programs, policies, or practices they describe are informed by research.

This finding is important as practitioner journals can play an integral role in promoting best practice in science education, and are often the only accessible source of research guidance for teachers. Some studies suggest that educators do not read or utilize original education research and this happens for any of the following reasons: they do not have time, they do not understand the education jargon written in the articles, they have negative feelings toward research, and/or they may not have the experience with academic writing to identify relevant research (Borg, 2010; Marsden & Kasprowicz, 2017; Sato & Loewen, 2018). Science education researchers who author SEPJ articles should reflect on whether their articles have mobilized research findings in an overt and accessible way for immediate use by practitioners.

These points, taken as a whole, raise the question of whether the research that academics publish in SEPJs and ARJs—conducted without the overt collaboration of practitioners via co-authorship—is as relevant to classroom-based teaching and learning as we might hope. While many researchers bring classroom experience to their work, their experience may or may not possess the contemporary classroom lens that can be provided by collaboration with active *K*–12 educators. Our findings raise the possibility that research findings published in science education journals may be difficult for SEPJ authors to mobilize for practitioners. However, we acknowledge that this assertion likely provides only a partial explanation of why peer-reviewed research is not more central to the content of SEPJ articles.

4.1 | Implications

Our discussion of implications is divided into two parts: near-term and long-term considerations. In both sections, we pose strategies and mechanisms for promoting bidirectional interaction via researcher–practitioner collaboration on journal articles—academic and practitioner focused—in science education. We discuss several strategies for exposing teachers to more accessible descriptions of research, including strategies that could facilitate enhanced research use in practitioner-focused articles.

4.1.1 | Near-term considerations

For increased use of research in SEPJs

Irrespective of the SEPJ or type of author (i.e., practitioners or researchers), we observed that the SEPJ articles had very few references to science education research journals. We consider it vital for improving classroom practices that SEPJ articles contain more explicit and direct connections to science education research journals. Hargreaves (2007) lamented that classroom teaching is not a research-based profession and believed that educational research has an insufficient impact on teaching practices. Others have generalized that teachers' perceive educational research as "irrelevant, unhelpful and too theoretical" (Hemsley-Brown & Sharp, 2003, p. 454), and criticized teachers' misconceptions about research, as well as negative opinions about the utility of research findings in education with regards to their classroom teaching (e.g., Labaree, 2003; Lysenko et al., 2014). Perhaps if practitioners saw more educational research represented in the body text and reference sections of exemplar

activities, such as those in SEPJ publications, their perception regarding the utility of academic research to their classroom would become more positive.

Overall, we suggest that SEPJ publishers could play a role in increasing the referencing of science education research articles, perhaps by requesting that SEPJ editors and reviewers encourage a judicious use of citations by their article authors, guiding authors to appropriately bring research into their manuscripts without gratuitous citation of articles (i.e., an unnecessarily large number of citations) that can have unwarranted negative effects on article length or readability. However, while such a change in practice may be well-received by science education researchers or other academic authors, this might be seen as an unreasonable request for practitioners who are writing SEPJ articles, at least without access to other forms of support, as they may not have access to academic collaborators or to research journal subscriptions.

For increasing collaborative authorship

One plausible reason for the lack of research references in current SEPJ articles written solely by practitioners is that they have not found academic literature to be insightful or meaningful in connection to their practice (Lysenko et al., 2014; Taber, 2013). Researchers collaborating with teachers on SEPJs articles could help connect empirical grounding to their practice or assist with organizing ideas based on a relevant theoretical perspective. It is also possible that domain-specific language in science education research—which some refer to as "jargon"—may be a barrier for some practitioners, and researchers could help to contextualize those ideas (see Baram-Tsabari et al., 2020; Bullock et al., 2019). Aside from co-authorship, another opportunity for correspondence has been created by *School Science and Mathematics*. This journal typically publishes research-focused articles, but recently added an "Innovation to Practice" short article format dedicated to chronicling STEM practitioner efforts. Authors who submit innovations to the journal go through the same double-blind review process and receive feedback from editors and reviewers, thus opening research to practice conversations. In our view, increasing classroom teachers' involvement in writing for research and/or practitioner audiences is an important way to incorporate and disseminate their classroom perspectives and experiences, thereby moving toward bidirectional collaborative work. Better connecting practitioners to research involvement is explored further in the long-term consideration section below.

In terms of the research-grounding of researcher–practitioner co-authored works, academic and practitioner authors can benefit from existing publisher supports—such as those provided for new researchers and authors whose first language is not English—which could be broadened to include guidance on grounding of SEPJs in the research literature. There are also learning communities of researchers and teachers whose primary focus is to support teachers in professional writing (see Damico & Whitney, 2017), a practice we believe should be more widespread. It would be understandably challenging for practitioner authors to cite the most relevant academic research without these or similar supports. In the end, the success of such an initiative to increase practitioner collaboration on the submission of SEPJ articles will rely on the extent to which their authorship is valued by the systems within which they work (and how they are rewarded for writing such articles). Success will also rely on the willingness of science education researchers to co-author SEPJ articles or otherwise support the research grounding of those articles.

For increasing practitioner access to research

Apart from increasing the visibility of science education research in SEPJ articles, there are other ways in which teachers and other practitioners can gain access to current research. First, it is important to recognize that accessing ARJs has historically required individuals to have a subscription, often provided through a university library or an affiliation (e.g., a professional organization like NARST). Currently, we are seeing changes in scholarly disciplines, including scientific and educational fields, due to the advancement of open science.[3] Authors are incentivized to publish open-access articles as they may benefit from increased readership and Altmetric attention.[4] Publishing articles openly removes some of the historical barriers for readers and makes information available to a broader audience, including practitioners and other education stakeholders. Below, we acknowledge two existing initiatives dedicated to broadening access to research and then discuss additional possible strategies.

We note first that the SEPJ publisher NSTA in the United States and NARST (the organization that supports the academic publication *Journal of Research in Science Teaching*) have a liaison that facilitates communication between their organizations and to achieve common goals (such as improving science education practices in both classroom and informal settings). This partnership produces a yearly list of three or four "Research worth Reading" articles, from the previous year's publications in *JRST*, for NSTA to promote to its practitioner members. As another example, the IES (IES, 2022c), through the What Works Clearinghouse, provides educators, policymakers, researchers, and the public access to databases, research reports, and reviews of the effectiveness of interventions including programs, products, practices, and policies. They also produce a series of products for practitioners that summarize research under the title "WWC Practice Guides". These are publications that present "recommendations for educators to address challenges in their classrooms and schools. They are based on reviews of research, the experiences of practitioners, and the expert opinions of a panel of nationally recognized experts." (IES, 2022c). These products address a number of topics related to science education but they are essentially limited to intervention research.

Beyond these existing mechanisms, we think that there are several other ways in which practitioners could become better connected to research in academic science education journals. First, we suggest that science education ARJs consider making available on the publisher's website a second abstract (in front of the subscription firewall) in the form of a one-page document describing the research for an informed lay person. This strategy is already being employed by the *New Journal of Physics* (New Journal of Physics, 2022) and the *Journal of Research on Educational Effectiveness* (JREE, 2022). The structure of these abstracts is consistent with the public-facing project abstracts employed on the National Science Foundation website (see NSF, 2022). Recently, *JRST* has started to pilot visual abstracts and research briefs. These new formats were identified as ways of sharing information with educational stakeholders outside of the immediate research community (Mensah & Sadler, 2021). Visual, or graphic, abstracts attract readers to articles and they are often created through a collaborative process between authors and designers. Their research brief is a one-page highlight of a published article that may be of interest to individuals who cannot access or may not typically read full-length research manuscripts. We believe the guidelines for these research briefs, or extended abstracts, could be specified to highlight the implications to educational practice where appropriate.

Second, publishers might consider offering a reduced subscription rate for their academic journal articles to verified classroom teachers, or even open-access to them. In the past, NSTA made one or two articles openly available from each issue. The *Journal of Science Teacher Education* (*JSTE*) is similarly available as a perk to members of the Association for Science Teacher Education, and the

journal still makes editorials and select articles free to access. One advantage of this strategy—more directly linking research publications to practitioner interests—is that it may encourage more practitioners to consider participating in research and scholarly writing.

Finally, social media tools could be better implemented to reach a practitioner audience. Academic articles with relevance to teachers could be promoted using tools such as Twitter, as could their extended abstracts if those were made available. *JRST*, in recent years, notably increased the social media presence for the journal (Mensah & Sadler, 2021). One of the goals is to expand their dissemination network to include audiences that typically do not have regular access to their journal content (e.g., teachers, administrators, and policymakers). The journal is using their social media platforms to promote articles, including the new research briefs and visual abstracts previously described. *JRST* research briefs are located on the NARST website, where tagging is being implemented for improved searchability (e.g., briefs that might be of interest for a specific audience, like *K*–12 teachers, could be tagged and bundled). We believe this is a worthwhile effort and recommend that other research journals in science education prioritize tagging articles with classroom applications so that they appear more often in web searches.

4.1.2 | Long-term considerations

Teacher involvement in the research process and development of articles can range from a semi-active role (e.g., critical friends) to active and full involvement as study designers/co-designers and authors. However, for teachers to become more familiar with the research enterprise, they need greater exposure to research norms, processes, and language. Similarly, researchers need to become more familiar with these same aspects of practitioner's work.

To increase the familiarity of teachers with the world(s) of researchers one could consider the use of a Legitimate Peripheral Participation framework where teachers would engage in a Community of Practice (Lave & Wenger, 1991) that includes researchers. In using an LPP approach, "newcomers" participate with experienced practitioners by first engaging in peripheral practices that are legitimate within the discipline and then over time engaging in practices that are more and more central to the practice/discipline being learned. In their seminal work where this framework was first presented, Lave and Wenger (1991) described how novices became enculturated in the practices of being a tailor:

> "Learning processes do not merely reproduce the sequence of production processes. In fact, production steps are reversed, as apprentices begin by learning the finishing stages of producing a garment, go on to learn to sew it, and only later learn to cut it out. This pattern regularly subdivides [the learning of] each new type of garment. Reversing production steps has the effect of focusing the apprentices' attention first on the broad outlines of garment construction as they handle garments while attaching buttons and hemming cuffs. Next, sewing turns their attention to the logic (order, orientation) by which different pieces are sewn together, which in turn explains why they are cut out as they are. Each step offers the unstated opportunity to consider how the previous step contributes to the present one. In addition, this ordering minimizes experiences of failure and especially of serious failure."
>
> (Lave & Wenger, 1991, p. 72)

So, how might this LPP framework be applied to helping teachers better understand educational research and its practices/products? Earlier, we posited that teachers being involved in academic writing for journals is a desired outcome, especially if it increased their appreciation of educational research and how it could be applied in their own classroom for their benefit and that of their students. To consider research participation from an LPP perspective requires identifying the trajectory from the most peripheral practices, such as reading research literature and conducting literature reviews, to the core practices of the production of academic writing about research, and all of the steps involved in research in between (see Roth & McGinn, 1998). As researchers ourselves, we note that many of us have involved teachers in our own research—but often in ways that do not necessarily reflect an LPP approach.

We are also left asking what the incentives would be for a teacher to participate in an LPP sequence of "steps" irrespective of the better understanding of educational research and its practices that might emerge from such an approach. Some incentives for teachers might include those that accelerate their professional trajectory and possibly their growth in compensation as well. For example, university collaborators may assign independent study or other credit to a practitioner's work on a publication. Many school districts base salary schedules in part on credits obtained beyond the baccalaureate degree. Thus, such course credit may contribute to an advanced degree and/or toward a teacher's next salary increase. Alternatively, school districts might allow teachers to write for publication as fulfillment of their professional development requirements for one or more school years. Other school district incentives might include giving teacher's additional time off to conduct research or write, either as part of the daily work schedule, or as dedicated full days toward research/writing. University collaborators may wish to seek new or use existing grant funding to facilitate such an incentive, paying for substitute teacher days that allow their practitioner colleagues to devote time to writing without creating financial hardships for school districts.

In addition to the incentives for teachers, it is important to develop a research publication system that will equally acknowledge the contributions of teachers and University collaborators in various aspects of the publication pipeline (e.g., idea generating, data collection and analysis, and writing the manuscript draft). This goal is currently far from the existing practice of publishing and will require a cultural shift for all contributing authors and journals' genres. Changing established practices of publishing articles requires time and strategic vision. To this end, we suggest considerations of journal special issues with elaborate co-design methodology and building a mentorship plan for the culture of writing for research journals. The scholars and practitioners who can utilize these suggested opportunities should also provide feedback to the field for improving the bidirectional contribution. We see that existing successful research-practice partnerships (e.g., Marshall et al., 2021; Novak & Khan, 2022; Penuel & Watkins, 2019) can have the extensive collaboration structure to set examples and provide feedback to the field on how journal articles can serve as a tool for bidirectional publication structure.

In his discussion of issues that arise with preparing educational researchers, Labaree (2003, p. 17) notes that "irreducible differences in the work roles occupied by teachers and researchers" lead to considerable differences in the worldviews of teachers and researchers which confounds teachers learning about educational research practices. An LPP-based approach would need to overcome such differences. Over and beyond that, an LPP-based-approach would seem to do little to develop the bidirectionality argued for earlier as the involvement of practitioners in research projects conducted by researchers for their purposes would do little to help the researchers become more familiar with the practitioner's work.

Perhaps a better strategy would be to encourage education researchers to support teachers in conducting action research. Encouraging teachers to engage in action research projects that inform them about their own classrooms—and might provide information that improves the classroom learning environment—could provide an incentive for teachers to participate more actively in research projects, avoiding some of the issues discussed by Labaree (2003) (e.g., perceived irrelevance of education research) and would help develop some of the desired bidirectional outcomes discussed earlier. These action research projects could be complementary to the main research of the educational researchers and could act as a scaffold toward teachers participating in larger, conceptually-oriented research projects. We note that the academics involved can also work with the teacher-researchers in writing about their projects in action research journals (e.g., *Educational Action Research* (EAR, 2022), the *Canadian Journal of Action Research* (CJAR, 2022), and *Sage Action Research* (SAR, 2022)) and such publications should carry the same weight in promotion and tenure considerations. Granting agencies can support this initiative by prioritizing classroom relevance, perhaps via action research, in the evaluation criteria for grant proposals in selected funding programs.

4.2 | Limitations

This study has several noteworthy limitations. At the global level, we acknowledge that researcher–practitioner collaboration can occur through multiple mechanisms (e.g., RPPs), as can knowledge be produced through multiple modes of collaboration. As such, this study examines journal article co-authorship as just one mechanism for promoting collaboration among researchers and practitioners. Any conclusions drawn in this study are limited to this mechanism.

Second, the conclusions we have drawn are limited to the specific timeframe (2013–2017) and journals analyzed in this study; NSTA and *Science Activities* as practitioner-focused journals and *JRST*, *Science Education*, *RISE*, and *IJSE* as academic journals. The number of journals and years analyzed were driven by the finite resources of the author team. We acknowledge the possibility that these conclusions could change had we analyzed a larger set of academic and practitioner-focused journals and done so in a longer and/or different timeframe. For example, with regard to time frame, we note that subsequent to the publication years included in this analysis, many changes have occurred recently for NSTA journals (Cathy Iammartino, personal communication, July 22, 2022) and these could result in more journal article references in SEPJ articles.

Further, we also couch our conclusions about research justification for instructional strategies and practices in SEPJs in the knowledge that journal articles are not the only source of such justification and the books that were cited in SEPJ articles also could provide such empirical support. Similarly, we also note that journal articles are not the only dissemination products where researcher–practitioner collaboration and co-authorship could have taken place. Although not accounted for in our analysis, other possible products of such collaboration include conference papers, books, research briefs, and state or local practitioner journals. Finally, we add that while a research study may be cited in a SEPJ article, in support of a program or practice, there is no guarantee that the study was cited correctly in providing such support. Therefore, we acknowledge that our citation counts, as indicators of practitioner exposure to research, may include instances where the use of the citation was not in congruence with the original research article.

5 | CONCLUSION

While there are several strategies for facilitation of researcher/practitioner collaboration (e.g., RPPs), and multiple products that researchers and practitioners can collaboratively produce, we assert that the metrics that we created in this study, to document citation of research in practitioner journals and rates of boundary crossing authorships, make a significant contribution to our understanding of bi-directional relationships and collaboration between researchers and practitioners. Further, the procedures of this study can be easily replicated to expand its scope and the findings are quantifiable. This allows for more objective monitoring of citation rates and authorship patterns over time, especially in response to future policies, incentives (for teachers and researchers), and collaborative structures/strategies for researchers and practitioners. The findings of this study can provide baseline levels and reference points for future analyses. Such future analyses could provide even further insight if journal editors began requiring that authors provide bios at the time of article acceptance. This would allow for more confident attribution of author affiliation for examining authorship patterns in ARJ and SEPJs.

As researchers, we view the findings of this study with some concern, while noting the limitations described previously. As individuals who produce research with the hope of improving learning in science classrooms, and who value a lens of relevance and practicality for our work, we hoped that we would observe greater bidirectionality in our interactions with practitioners. It brings to mind Merton's classic paper on "Unanticipated Consequences" (Merton, 1936)—where purposive actions for some outcomes have unexpected outcomes in other areas. Those of us who have written articles for SEPJs have not been told to limit references to academic journals, but the reality is that often we have. At the same time, many of the articles that are written for SEPJs seem to have few overt connections to education research and are often closely linked to a single classroom activity (akin to a lesson plan), so perhaps that preferred format and focus led to the unanticipated outcome of disconnection from science education research.

Now that we as a community of science education researchers are more aware that our research work is infrequently referenced in practitioner journals, it is now incumbent on us to reflect on why that might be happening and to address that in our own actions. Is our research writing too jargon-filled for teachers to apply? Is the focus of the typical academic study too abstract for a practitioner to apply in a classroom? Or is the writing strictly about the research and not its application? Should part of our routine writing task as academics be to produce "short" versions of our academic papers with content specifically geared towards classroom practice and practitioners? Should our ARJs and funding agencies be requiring non-academic translations of research? Or should we go further as a community? Should science education ARJs be explicitly aligned with a practitioner journal, providing a direct outlet for academic papers to be re-published, written in a more practitioner-accessible format? We suggest that our community consider one or more of these strategies.

Collectively, our findings suggest a period of reflection in our research community. During such reflection, we should be asking ourselves why we conduct our research if it is not to ultimately influence classroom practices and improve student outcomes. If these are indeed part of our goals in doing research, then we need to consider how we can better accomplish that, and how we can best leverage practitioners as collaborators in those efforts.

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ENDNOTES

[1] Around the world we continue to hear calls for policy and practice to be guided by evidence derived from research. Knowledge mobilization (KMb) is a term that emerged in response to concerns over the research-practice gap. Cooper et al. (2009) introduce this term and outlined issues and challenges that arise from the increased interest in evidence and research use in education. This area of scholarship is grounded in models of research use (Weiss, 1979), related literature on knowledge dissemination (Louis, 2005), and the diffusion of innovation (Roger, 1995).

[2] Universities are the largest producers of research in education, yet third-party mediators play a powerful role in shaping what is considered evidence-based practice. In defining knowledge mobilization, Cooper et al. (2009) explain that most people, including most professionals, get their knowledge of research through various mediating processes rather than by reading primary literature. These processes may include professional development events, the work and publications of professional associations (e.g., NSTA), materials summarized by government agencies or lobbying groups, materials shared by employers and media sources (including social media).

[3] Open science is based on the premise that research should be transparent and reproducible, and fulfilling these conditions will yield more trustworthy and, ultimately, more useful findings (Cook et al., 2018, as referenced by Sadler & Mensah, 2020). You can review the open access information for authors provided by Wiley: https://authorservices.wiley.com/open-research/open-access/index.html

[4] The authors of this study recognize that open access also shifts some of the burdens associated with access to academic research journals (e.g., authors often pay a publication fee for open access rather than readers paying to access an article), so it is not our intent to portray open access as a universal solution. For more discussion about the direction of open science see Kessler et al. (2021). Wiley shares information about the advantages of open access based on paper downloads and citations from 2015 to 2021, follow the link provided for more information: https://onlinelibrary.wiley.com/page/journal/1098237x/homepage/oa-advantages

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