



A scoping review of health profession students as stakeholders in science diplomacy

Un examen del rol de los estudiantes de profesiones de la salud como actores en diplomacia científica

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KEY WORDS

Science diplomacy, student stakeholder, internationalization of medical education, global collaboration, health profession students, review

ABSTRACT

During the COVID-19 pandemic, international collaboration proved essential in developing treatments, diagnostics, and clinical trials to combat the virus. This global effort highlighted the importance of "science diplomacy" (SD)—a term describing the intersection of scientific collaboration and international relations—in advancing global health and shaping policy. Despite its growing significance, SD remains underexplored in medical education. Our review addresses this gap by 1) emphasizing SD's role in science and healthcare during the pandemic, 2) assessing its inclusion in medical school curricula, and 3) proposing strategies to integrate SD into medical education. To evaluate SD's influence during COVID-19, we reviewed its impact on health outcomes and international cooperation. For the second objective, we analyzed 59 peer-reviewed papers (2000–2023) to determine the presence of SD in medical curricula. Finally, we provide recommendations to prepare healthcare professionals for diplomatic efforts that promote global health equity. By incorporating SD, medical schools can better equip professionals to address global health challenges through collaboration and diplomacy. This project is among the first to explore the intersection between medical education and SD, shedding light on potential shortfalls in our educational system and paving the way for more comprehensive curriculum practices.

PALABRAS CLAVE

Diplomacia científica, estudiantes interesados, internacionalización de la educación médica, colaboración internacional, estudiantes de profesiones de la salud, examen

RESUMEN

Durante la pandemia de COVID-19, la colaboración internacional fue clave para desarrollar tratamientos, herramientas de diagnóstico y ensayos clínicos, destacando la necesidad de cooperación global. En este contexto, surgió el concepto de "diplomacia científica" (DS), que juega un papel crucial en el avance de la salud global y la formulación de políticas. Sin embargo, la literatura actual no aborda la inclusión de la DS en los planes de estudio de las facultades de medicina ni explora su relación con la práctica médica. Nuestra revisión tiene tres objetivos: 1) destacar la relevancia de la DS en ciencia y salud, especialmente desde la pandemia; 2) evaluar su incorporación en los planes de estudio médicos; y 3) proponer estrategias para integrar la DS en la educación médica. Para ello, analizamos el impacto de la DS durante la pandemia, revisamos 59 artículos publicados entre 2000 y 2023 y desarrollamos recomendaciones concretas

para preparar a los profesionales de la salud en iniciativas diplomáticas que fomenten la equidad y cooperación global. Este proyecto pionero identifica brechas en la educación médica relacionadas con la DS y plantea soluciones para integrar este enfoque, mejorando la preparación de los profesionales ante retos de salud global.

1. INTRODUCTION

1.1. *Defining Science Diplomacy*

The COVID-19 pandemic underscored the importance of international collaboration as a means to respond more effectively to the spread of the virus. The rapid development of treatments and diagnostic tools, along with clinical trials and research, was shared across borders. Organizations such as the World Health Organization (WHO) facilitated the sharing of information about the outbreak. Resources such as the Global Initiative on Sharing All Influenza Data (GISAID), which has rapidly become the world's largest repository of genome sequences, allowed scientists to share genomic sequences of the virus, aiding in tracking mutations and understanding the spread of different variants. Analyses revealed that GISAID's citation rate increased in the realm of COVID-19 research, and the database was deemed crucial for vaccine development and extensive virus monitoring (Khare et al., 2021).

To contextualize this article, it is essential to define the concept of "science diplomacy" (hereafter referred to as SD) and its three commonly recognized dimensions (European External Action Service). SD can be broadly understood as: (1) diplomacy for science, which involves leveraging diplomatic efforts to promote international scientific collaboration; (2) science for diplomacy, which employs science as a form of soft power to build bridges between nations and enhance diplomatic relations; and (3) science in diplomacy, which integrates scientific expertise into diplomatic processes, providing evidence-based support to inform foreign policy and security decision-making.

The broad scope of SD reflects its intersection with science, technology, and international relations, encompassing domains such as foreign affairs, security, and global development (Flink & Ruffini, 2019). For the purposes of this discussion, SD is conceptualized specifically as diplomacy for science. This dimension uses diplomatic tools to advance scientific endeavors by creating collaborative opportunities across national and cultural boundaries. In this context, SD positions scientists as pivotal contributors to policy-making, offering pathways to tackle global issues collectively. This interpretation aligns with the authors' focus on the role of scientific partnerships in building constructive and cooperative global networks.

1.2. *SD and the Health Profession*

Health professionals occupy a distinct and influential role within societies, earning the trust and respect of the public due to their commitment to service and dedication to improving health outcomes. Globally, health-care providers share a common mission: to advance health and well-being for everyone. This objective aligns closely with the goals of science diplomacy (SD), which similarly emphasizes public service, humanitarian engagement, and the collective good. Health professionals are inherently invested in humanitarian work, often spearheading or contributing to initiatives aimed at addressing health disparities and improving outcomes for underserved communities. Their professional standing not only enables them to provide direct patient care but also positions them as powerful advocates for health policy, leveraging their expertise and societal trust to shape and inform public health decisions.

As an accessible and visible group within society, health professionals are uniquely placed to bridge the gap between the scientific community and the general public. Their direct interactions with patients allow them to serve as conduits for accurate health information, making them indispensable in countering misinformation and promoting evidence-based practices. In this capacity, they extend their impact beyond clinical care, playing a critical role in fostering public trust in science and supporting the broader objectives of health diplomacy. The healthcare profession's focus on public welfare and its widespread accessibility across diverse populations make its members natural allies in SD efforts. Their involvement in international collaboration can strengthen relationships between nations and contribute to the resilience of global health systems through a shared commitment to equity. Consequently, integrating SD principles into the training of health professionals enhances their ability to collaborate across borders, while also empowering them to advocate

for policies that promote health equity and resilience on a global scale (De Wit & Altbach, 2020; Koehn & Swick, 2006).

1.3. Barriers Between Healthcare Professionals and SD

Historically, the field of SD has not overlapped significantly with the lines of healthcare; The flow of information between scientists, healthcare professionals, and diplomats is often inefficient, with important data and insights not shared effectively or in a timely manner. The overall lack of institutional frameworks that facilitate seamless cooperation between healthcare providers and diplomatic organizations only further contribute to this gap. This disconnect is expected, however, as the healthcare profession often focuses on patient care and health outcomes, while SD prioritizes international cooperation and policy development (Almeida, 2020). Thus, the culture in healthcare, which is often more structured, differs from the collaborative and sometimes slower-paced nature of diplomatic negotiations. Beyond pacing, the technical language used by healthcare professionals also differs from the diplomatic language in international relations. Ultimately, important health data and research findings may not be properly shared with diplomatic entities, resulting in knowledge gaps. This contrast creates barriers between the fields of healthcare and SD, although both fields aim to ensure the well-being and health of populations through effective healthcare delivery and international cooperation (Bonilla et al., 2021).

Thus, the question remains: how can this gap be effectively bridged? The authors assert that healthcare professionals and researchers would greatly benefit from specialized training in SD. But when should this training take place, and how should it be implemented? It is inarguable that the earlier this training starts, the better. Medical students with training in SD would be better prepared to advocate for policies that promote global health security, such as regulations on the use of antibiotics, frameworks for pandemic preparedness, and agreements on climate change mitigation. Medical professionals with a background in SD could advocate for equitable distribution of medical resources, ensuring that underserved populations receive the care they need. Moreover, understanding SD enables medical students to appreciate the broader context of their work. It fosters an awareness of how global policies impact local health outcomes, encouraging a more holistic approach to healthcare. This perspective is crucial in addressing health disparities and promoting health equity on a global scale.

Incorporating SD into medical education also prepares students for leadership roles in international organizations, such as the World Health Organization (WHO), the United Nations (UN), and non-governmental organizations (NGOs). The WHO is primarily governed by the World Health Assembly (WHA)—which recruits health ministers from 194 member states (*World Health Organization*). Together, they prioritize specific health issues, develop policies to address global health challenges, and determine the allocation of resources to meet global health priorities. It is thus crucial that these responsibilities are strongly informed by medical expertise, and that doctors rise up to the occasion to take on these roles.

As the world becomes more interconnected, the need for medical professionals who can bridge the gap between science and diplomacy will only grow. It is imperative that medical education evolves to meet this need, equipping students with the knowledge and skills to thrive in an increasingly globalized healthcare environment.

1.4. Objectives

This consideration naturally progresses to the inquiry: "Is science diplomacy currently being integrated into medical school curricula?" Despite the growing recognition of the importance of SD in addressing global health challenges, a general lack of integration into medical school curricula is expected.

To better evaluate the current state of science diplomacy (SD) education in medical schools, this scoping review seeks to: 1) delineate and underscore the significance of science diplomacy in medical science and healthcare; 2) investigate whether science diplomacy is included in or examined within medical school curricula; and 3) propose pathways for more effective integration of science diplomacy into the educational framework based on these findings.

Addressing the first objective involves examining the role of SD in facilitating international collaborations, addressing global health crises, and promoting equitable access to healthcare. For the second objective, the authors will conduct a comprehensive review of existing literature to determine whether, and how, science diplomacy is being taught in medical schools. Compiling and analyzing these sources will provide a clearer

picture of the current landscape of SD education in medical schools. Lastly, addressing the third objective involves proposing innovative approaches—such as interdisciplinary methods, specialized courses, and institutional partnerships—to integrate science diplomacy into medical education and prepare healthcare professionals to address global health challenges.

In this scoping review of sources related to science diplomacy (SD), the authors aim to identify existing gaps that may have implications for the medical education community. The article examines the extent to which SD initiatives have been integrated into medical education thus far. This research is crucial for medical educators, not only to understand the underlying motivations but also to develop standardized curricula and effectively implement this teaching. Given that SD remains a relatively underexplored area, this study has the potential to pave the way for a more comprehensive and well-rounded medical education system.

2. METHODS

2.1. Identification of Relevant Studies

Google Scholar, Pubmed and Frontier databases were included in the literature search in order to focus on both peer-reviewed health sciences and non-health related scientific journals (Figure 1). Searches included articles published from January 1, 2000 to July 1, 2024. This timeframe was chosen based on the general increase in focus on internationalization efforts in various health professions that emerged shortly after the turn of the 21st century. Prior to this period, publications on internationalization within health professions were relatively sparse. The searches for this study were conducted between March 2024 to July 2024.

Because the term “science diplomacy” is still not widely used, the key words “international” and “medical education” were intentionally used to initially narrow down potentially relevant papers. Titles and abstracts were then manually scanned to more accurately determine if they would be important for the study.

Inclusion criteria were limited to the following topics: SD, internationalization efforts and postgraduate medical education (Figure 1). All languages were considered in the review. However, articles not written in English were flagged to indicate that their content could not be validated and were therefore excluded from the final analysis. Nonetheless, English-language abstracts were included.

This review includes only peer-reviewed journal articles to provide a rigorous and credible foundation for examining the intersection of science diplomacy and medical education. Peer-reviewed sources undergo

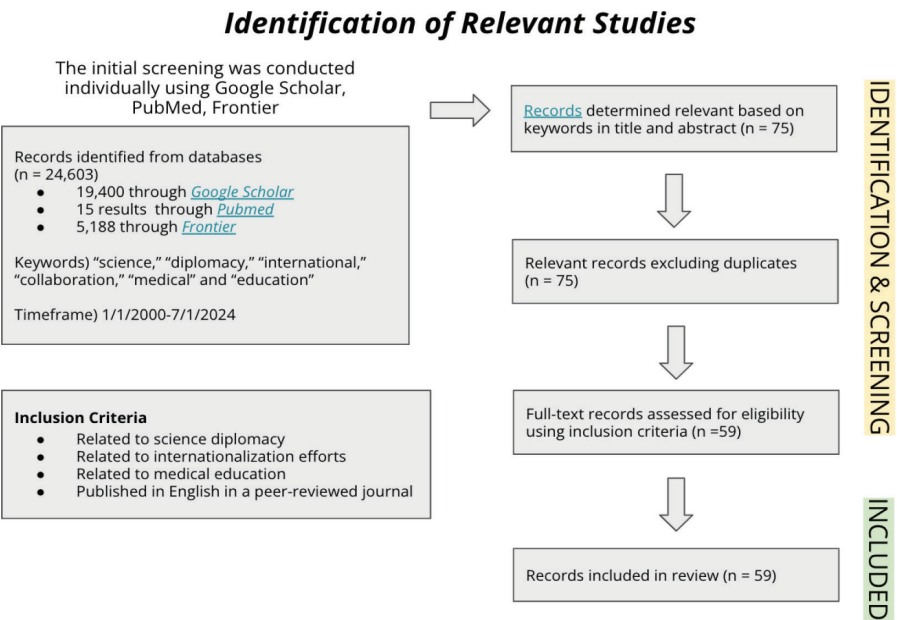


Figure 1. Identification of Relevant Studies.

Flow diagram illustrating the literature search and selection process for studies included in the scoping review. Databases searched included PubMed, Google Scholar, and Frontiers, covering publications from January 2000 to July 2024. After screening titles and abstracts and applying inclusion/exclusion criteria, 59 articles were retained for final analysis

extensive evaluation, ensuring a higher standard of accuracy and reliability, which is essential in a field that remains methodologically complex and still in its developmental stages. This approach also emphasizes a critical point: the relative scarcity of scholarly literature in this area. By focusing on peer-reviewed publications, this review highlights the need for more comprehensive, empirically grounded research on this intersection. While blogs and websites may offer useful perspectives, they often lack the quality control necessary for scholarly analysis, where the emphasis is on substantiated, peer-validated insights.

A total of 59 articles were found suitable for review (Figure 1). The initial screening of titles and abstracts was conducted independently, followed by group discussions. The team convened a couple times to address discrepancies concerning inclusion or exclusion criteria until consensus was achieved. The final decision on any unresolved matters was made by the senior author.

2.2. Charting of Data

Thematic coding was used to sort articles into categories of concepts for the purposes of the study. These concepts included: (1) defining SD, (2) underlining the significance of SD in the realm of science and health-care, and (3) examining SD in the field of education. Once these themes were identified, the articles were arranged into chart format (Table 1).

Table 1. Thematic Organization of Literature. Categorization of 59 articles by thematic focus (Science Diplomacy in Health, Policy, and Education), including reference, title, publication year, article type, and country of origin.

Thematic Category	References	Title	Year Published	Type of Article	Originating Country
SD in Health	Elbe & Buckland-Merrett	Data, disease and diplomacy: GISAID's innovative contribution to global health	2017	Case study	UK
SD in Health	Katz et al.	Defining health diplomacy: changing demands in the era of globalization	2011	Commentary	USA
SD in Health	Nguyen et al.	International collaboration in scientific research in Vietnam: an analysis of patterns and impact	2017	Statistical analysis	Vietnam
SD in Health	Liu et al.	China's distinctive engagement in global health	2014	Literature Review	China, USA
SD in Health	Crane	Unequal 'partners'. AIDS, academia, and the rise of global health	2010	Commentary	USA
SD in Health	Lee	Vaccine diplomacy: nation branding and China's COVID-19 soft power play	2021	Case study	USA
SD in Health	Ansari et al.	Collaboration and partnerships: developing the evidence base	2001	Commentary	UK
SD in Health	Bonilla et al.	The Role of Science Diplomacy in Global Health: The Case of Ecuador	2021	Survey	Brazil, Guatemala
SD in Health	Chattu et al.	The rise of India's global health diplomacy amid COVID-19 pandemic	2023	Statistical Analysis	India
SD in Health	Birn	Philanthrocapitalism, past and present: The Rockefeller Foundation, the Gates Foundation, and the setting (s) of the international / global health agenda	2014	Commentary	Canada
SD in Health	Bedford et al.	A new twenty-first century science for effective epidemic response	2019	Commentary	UK, Nigeria, India, Netherlands, Ethiopia
SD in Health	Kocarnik et al.	Cancer Incidence, Mortality, Years of Life Lost, Years Lived With Disability, and Disability-Adjusted Life Years for 29 Cancer Groups From 2010 to 2019: A Systematic Analysis for the Global Burden of Disease Study 2019	2021	Statistical Analysis	USA, Iran, more
SD in Health	Vos et al.	Global burden of chronic respiratory diseases and risk factors, 1990-2019: an update from the Global Burden of Disease Study 2019	2023	Statistical Analysis	Iran, Germany, USA, more

(continued)

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(continued)

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SD in Health	Bezak et al.	Science diplomacy in medical physics - an international perspective	2023	Commentary	Australia, UK, USA, more
SD in Health	Cunha et al.	The Global, Regional, and National Burden of Adult Lip, Oral, and Pharyngeal Cancer in 204 Countries and Territories: A Systematic Analysis for the Global Burden of Disease Study 2019	2023	Statistical Analysis	Brazil, USA, more
SD in Health	Zanetti et al.	Diplomatic response to global health challenges in recognizing patient needs: A qualitative interview study	2023	Survey	Belgium, Croatia, USA
SD in Policy	Pandi-Perumal et al.	Harbingers of Hope: Scientists and the Pursuit of World Peace	2023	Commentary	India, Belgium, more
SD in Policy	Pandi-Perumal et al.	Scientists Against War: A Plea to World Leaders for Better Governance	2022	Commentary	Canada, India, USA, more
SD in Policy	Paglia	The Swedish initiative and the 1972 Stockholm Conference: the decisive role of science diplomacy in the emergence of global environmental governance	2021	Commentary	USA
SD in Policy	Flink & Schreier	Science diplomacy at the intersection of S&T policies and foreign affairs: toward a typology of national approaches	2010	Comparative analysis	Germany
SD in Policy	Polejack	The Importance of Ocean Science Diplomacy for Ocean Affairs, Global Sustainability, and the UN Decade of Ocean Science	2021	Literature Review	Sweden, Brazil
SD in Policy	Pandey et al.	Emerging Technologies, STI Diaspora and Science Diplomacy in India: Towards a New Approach	2022	Commentary	India
SD in Policy	Fedoroff	Science diplomacy in the 21st century	2009	Commentary	USA
SD in Policy	Labonte & Gagnon	Framing health and foreign policy: lessons for global health diplomacy	2010	Analysis	Canada
SD in Policy	Amorim et al.	Oslo Ministerial Declaration—global health: a pressing foreign policy issue of our time	2007	Commentary	Brazil, France, Indonesia, Norway, Senegal, South Africa, Thailand
SD in Policy	Carayannis & Campbell	Open innovation diplomacy and a 21st century fractal research, education and innovation (FREIE) ecosystem: building on the quadruple and quintuple helix	2011	Commentary	USA, Austria
SD in Policy	Soler	Science Diplomacy in Latin America and the Caribbean: Current Landscape, Challenges, and Future Perspectives	2021	Commentary	Spain, Mexico
SD in Policy	Lopez-Verges et al.	Closing the Gap Between Emerging Initiatives and Integrated Strategies to Strengthen Science Diplomacy in Latin America	2021	Comparative Analysis	Panama, Mexico, Costa Rica, Spain
SD in Policy	Toro et al.	The needed link between open science and science diplomacy—A Latin American perspective	2024	Survey	France and more
SD in Policy	Prieto & Scott	Scientific diasporas and the advancement of science diplomacy: The InFEWS US-China program in the face of confrontational “America First” diplomacy	2022	Descriptive analysis	USA
SD in Policy	Pouliot & Cornut	Practice theory and the study of diplomacy: A research agenda	2015	Commentary	Canada

Thematic Category	References	Title	Year Published	Type of Article	Originating Country
SD in Policy	Jarquín-Solis & Mauduit	Institutional Capacity for Science Diplomacy in Central America	2021	Descriptive analysis	Costa Rica, UK
SD in Policy	Wagner et al.	The continuing growth of global cooperation networks in research: A conundrum for national governments	2015	Statistical analysis	USA, South Korea, Netherlands
SD in Policy	Polejack & Coelho	Ocean Science Diplomacy can Be a Game Changer to Promote the Access to Marine Technology in Latin America and the Caribbean Updated	2021	Analysis	Sweden, Brazil
SD in Policy	Elzinga	Features of the current science policy regime: Viewed in historical perspective	2012	Commentary	Sweden
SD in Policy	Feldbaum & Michaud	Health diplomacy and the enduring relevance of foreign policy interests	2010	Commentary	USA
SD in Policy	Echeverría-King et al.	Organized Scientific Diaspora and Its Contributions to Science Diplomacy in Emerging Economies: The Case of Latin America and the Caribbean	2022	Survey	Colombia, more
SD in Policy	Bonilla et al.	Participation in Communities of Women Scientists in Central America: Implications From the Science Diplomacy Perspective	2021	Survey	Brazil, Guatemala, more
SD in Policy	Butler et al.	Recognize and Alleviate a Resource Management Conundrum Facing Science Diaspora Networks	2022	Survey	USA
SD in Policy	Silva et al.	The Institutional Building of Science and Innovation Diplomacy in Latin America: Toward a Comprehensive Analytical Typology	2021	Analysis	Switzerland, Brazil
SD in Education	Koehn & Swick	Medical education for a changing world: moving beyond cultural competence into transnational competence	2006	Commentary	USA
SD in Education	Knight	International universities: Misunderstandings and emerging models?	2015	Comparative Analysis	Canada
SD in Education	Hill	Evolution of education for international mindedness	2012	Commentary	Switzerland
SD in Education	Büger & Gädinger	Reassembling and dissecting: International relations practice from a science studies perspective	2007	Commentary	Italy, Germany
SD in Education	Dolby & Rahman	Research in international education	2008	Comparative analysis	USA
SD in Education	Paradis & Whitehead	Beyond the lamppost: a proposal for a fourth wave of education for collaboration	2018	Commentary	USA, Canada
SD in Education	Caverzagie et al.	Overarching challenges to the implementation of competency-based medical education	2017	Commentary	USA, Canada
SD in Education	Croix et al.	Arts-based learning in medical education: the students' perspective	2011	Descriptive analysis	UK
SD in Education	Amuguni et al.	Building a framework for the design and implementation of one health curricula in east and central africa	2018	Commentary	Uganda
SD in Education	Jogerst et al.	Identifying interprofessional global health competencies for 21st-century health professionals	2015	Literature Review	USA
SD in Education	Olum et al.	Medical education and E-learning during COVID-19 pandemic: awareness, attitudes, preferences, and barriers among undergraduate medicine and nursing students	2020	Survey	Uganda

(continued)

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(continued)

Thematic Category	References	Title	Year Published	Type of Article	Originating Country
SD in Education	Wilhelmsson et al.	Twenty years experiences of inter-professional education in Linköping—ground-breaking and sustainable	2009	Case study	Sweden
SD in Education	Aven-daño-Uribe et al.	Engaging Scientific Diasporas in STEM Education: The Case of Science Clubs Colombia	2022	Case study	Colombia, New Zealand, USA, more
SD in Education	Wu	Reshaping internationalization of medical education in 2023	2023	Commentary	USA
SD in Education	Kron et al.	Academic Medicine and Science Diplomacy: Medical Education in Iraq	2019	Case study	USA, Iraq
SD in Education	Mauduit & Soler	Building a Science Diplomacy Curriculum	2020	Commentary	UK, Italy
SD in Education	Zhang et al.	The landscape of flipped classroom research: a bibliometrics analysis	2024	Literature Review	China
SD in Education	Wu et al.	Editorial: Teaching and learning in a global cultural context	2024	Commentary	USA
SD in Education	Wu et al.	A Scoping Review of Internationalization of Dental Education—Identifying Formats and Motivations in Dental Education	2022	Literature Review	USA

3. RESULTS

Overall, the literature search identified 59 articles published between 01/01/2000 and 7/1/2024. Thematic coding of articles shed light on an overwhelming lack of publications revolving around SD within the context of education.

3.1. Origin of Articles

The analysis of the selected articles revealed a total of 34 countries represented in the publication landscape. The majority of these papers originated from high-income countries (HICs), indicating a significant disparity in research output across different economic contexts. Notably, eight lower-middle-income countries (LMICs) were identified, specifically: Vietnam, Uganda, Indonesia, Nigeria, Ghana, Senegal, and Ethiopia (Amorim et al., 2007; Amuguni et al., 2018; Bedford et al., 2019; Bonilla et al., 2024; Nguyen et al., 2017; Olum et al., 2020). This highlights the growing participation of LMICs in global health research, although their overall contribution remains limited compared to HICs.

Furthermore, collaborative efforts among multiple countries were evident, as 30 out of 59 articles (50.8%) resulted from international partnerships. This underscores the importance of collaborative research in enhancing the quality and scope of scientific inquiry, particularly in addressing global health challenges that transcend national boundaries.

In addition to the geographic analysis, it was observed that three authors within the cohort were identified as highly productive, each having more than one publication in the final selection of articles. This concentration of authorship suggests a potential network of influence and expertise that could be leveraged to further advance research in the respective fields.

Moreover, we observed an intriguing shift in the publication trends following the COVID-19 pandemic (Figure 2). Prior to 2020, the number of articles published annually on the intersection of sustainable development (SD) and education remained relatively low, with many years producing only a handful of studies. However, as the pandemic unfolded, there was a notable surge in the number of published articles. This increase could be attributed to several factors.

First, the pandemic illuminated the vulnerabilities of educational systems worldwide, likely prompting researchers to reassess and adapt their approaches to education within the framework of sustainability

(Chattu et al., 2023). The urgency to address educational disruptions, combined with the need for innovative solutions, may have catalyzed a significant uptick in publications focused on SD in education. Scholars may have shifted their attention to exploring how educational institutions can enhance resilience and adaptability in the face of crises.

We observed a marked increase in the number of articles published post-2020, reflecting a growing interest in addressing SD within educational contexts (Figure 2). The spike of publications in 2021 suggests that the pandemic may have served as a catalyst, driving both established and emerging researchers to contribute to this important area of study.

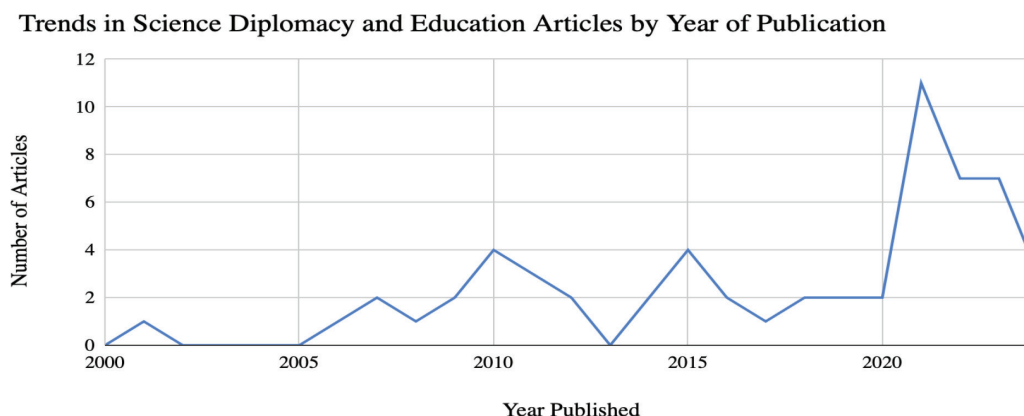


Figure 2. Trends in SD and Education Articles by Year of Publication.

Graph depicting the number of publications addressing science diplomacy (SD) and education between 2000 and 2024. A notable surge in 2021 reflects heightened academic attention following the COVID-19 pandemic

These findings contribute to our understanding of the global research landscape, particularly the interplay between economic status and scientific output, while also emphasizing the value of collaboration in addressing complex health issues.

3.2. Type of Articles

The analysis of the 59 articles demonstrated a wide range of topics and methodologies, with a predominant emphasis on descriptive studies. Notably, 27 articles (45.8%) were categorized as commentaries, highlighting the significance of theoretical discourse and expert opinion in shaping contemporary understanding within the field. This prevalence underscores the critical role of reflective analysis in informing research agendas and guiding future inquiries.

In terms of empirical research, 6 articles (12%) employed statistical analysis, indicating an engagement with quantitative data to substantiate findings. Furthermore, 5 articles (8.5%) focused on comparative analyses, showcasing an interest in examining variances and similarities across different contexts.

The inclusion of 4 case studies (6.8%) provided in-depth examinations of specific instances, enhancing the qualitative understanding of the subjects under investigation. Additionally, the presence of 5 literature reviews (8.5%) underscores the importance of synthesizing existing research to offer a comprehensive overview of the current state of knowledge in the discipline.

Surveys were featured in 9 articles (15.3%), reflecting a methodological approach aimed at collecting quantitative data to inform the discussions. Moreover, 3 articles (5.1%) were classified as descriptive analyses, with another 3 articles (5.1%) identified simply as analyses, further illustrating the variety of research methodologies employed within this body of literature.

Overall, the distribution of article types reveals a multifaceted engagement with various research methods and topics, contributing to a robust understanding of the issues at hand. This varied methodological approach is essential for fostering a comprehensive dialogue in the field and advancing best practices in future research endeavors.

3.3. *Science Diplomacy in the Context of Medical Education*

The analysis of motivations underlying the selected studies reveals a significant focus on enhancing global health outcomes through collaborative mechanisms and innovative strategies. For example, the role of Global Initiative on Sharing All Influenza Data (GISAID) in advancing data-sharing initiatives demonstrates how effective information exchange can facilitate epidemic response and disease surveillance (Elbe & Buckland-Merrett, 2017). This theme aligns with the concept of vaccine diplomacy, wherein nations utilize health initiatives to strengthen their international positioning while simultaneously addressing urgent health crises, particularly highlighted during the COVID-19 pandemic (Lee, 2021). These initiatives underscore the critical importance of international partnerships in mitigating health challenges and improving public health resilience.

Additionally, the imperative to reform medical education to incorporate global competencies has emerged as a crucial factor in preparing health professionals for the complexities of a dynamic healthcare landscape (Wu & Preker, 2023). Recent studies advocate for evolving educational frameworks that prioritize transnational competence, moving beyond traditional cultural competence to foster a comprehensive understanding of global health dynamics. Concurrently, the integration of science diplomacy into foreign policy is posited as a means to leverage scientific collaboration for addressing pressing global issues, such as environmental sustainability. Collectively, these motivations reflect a transformative approach to health diplomacy, education, and international collaboration, aiming to foster a more cohesive and effective response to global challenges.

4. DISCUSSION

4.1. *Gaps*

Despite its growing relevance at the intersection of science, technology, policy, and international relations, the field of science diplomacy remains underdeveloped in both conceptual clarity and academic reporting. While there are notable examples of successful initiatives—such as global health collaborations and environmental governance frameworks—systematic studies that define, categorize, and assess science diplomacy efforts remain limited. This lack of structure raises concerns about the ability of science diplomacy to evolve into a robust and standardized discipline.

A key challenge in the advancement of science diplomacy is the absence of consistent terminology and agreed-upon frameworks (Katz et al., 2011). Many publications addressing global scientific collaborations or cross-border health initiatives do not explicitly identify their efforts as science diplomacy (Dolby & Rahman, 2008). As a result, valuable insights into policy-relevant scientific exchanges are often scattered across disciplines—such as environmental studies, global health, and international education—without being synthesized into a cohesive body of knowledge.

Despite the use of broad search terms and inclusive criteria, identifying focused academic work remains challenging. Topics such as "vaccine diplomacy," "ocean science diplomacy," or "international scientific partnerships" appear in various fields but lack alignment under a unified definition. This conceptual fragmentation hampers the development of a core identity for science diplomacy, preventing scholars and practitioners from drawing lessons across domains.

In the past two decades, the volume of peer-reviewed literature on science diplomacy has remained modest, which limits the resources available to develop frameworks that prepare healthcare professionals to engage in global health diplomacy. Moreover, among the small number of SD publications that do exist, many focus on case-specific studies rather than broader, systematic analyses. For instance, studies on specific cases—such as China's health diplomacy, Latin American environmental initiatives, or the Rockefeller Foundation's global health efforts—offer localized perspectives but do not collectively form a comprehensive framework (Birn, 2014). A notable trend is the dominance of contributions from certain institutions or regions, leaving many emerging economies underrepresented in the discourse. This imbalance highlights the need for more inclusive research that reflects diverse geopolitical perspectives and regional experiences.

In addition to these case-specific studies, approximately half of the existing literature consists of commentaries on the absence of science diplomacy in medical education. While these commentaries are important for highlighting the gaps in training and raising awareness about the necessity of science diplomacy in

global health, they often lack empirical evidence on the tangible outcomes of such integration. Many initiatives—such as transnational health programs or the involvement of scientific diasporas—remain undocumented or confined to grey literature and policy reports (Pandey et al., 2022). There is a clear need for more outcomes-focused research to assess the impact of embedding science diplomacy into medical curricula. Specifically, studies are needed to examine how exposure to science diplomacy influences healthcare professionals' ability to navigate complex global health challenges, collaborate across borders, and address international health crises. Moreover, outcomes research could highlight which pedagogical models are most effective in imparting science diplomacy skills, and how these models can be adapted to diverse regional and cultural contexts to enhance their relevance and impact on global health diplomacy. Without this kind of evidence, it remains difficult to determine the real-world benefits of integrating science diplomacy into medical education or to justify its inclusion in curricula on a global scale.

Science diplomacy, much like global health diplomacy, is still in its formative stages, with a limited pool of experts actively contributing to its development. The field relies heavily on a small number of scholars, often from the same institutions or research networks, resulting in a concentrated body of work that may not fully capture the global diversity of science diplomacy practices (Pandi-Perumal et al., 2022). Moreover, many of the individuals driving this work operate at the intersection of multiple disciplines—such as environmental science, public health, and international policy—facing challenges in finding appropriate publication platforms or collaborative networks.

In the realm of education, medical schools traditionally emphasize clinical and biomedical training—a well-established norm rooted in the primary objective of preparing students to diagnose and treat individual patients effectively. This focus is driven by a curriculum that prioritizes foundational medical sciences, such as anatomy, physiology, biochemistry, and pharmacology, along with extensive clinical training in various specialties like internal medicine, surgery, pediatrics, and obstetrics.

The structure of medical education is typically dense and time-constrained, leaving little room for subjects perceived as peripheral to direct patient care. This comes at the expense of broader educational elements, such as public health, health policy, and interdisciplinary fields like science diplomacy. As a result, topics that address the wider context of healthcare delivery, including the socio-political, economic, and international dimensions of health, may receive minimal attention.

4.2. *Equipping Medical Professionals with Skills in SD*

Rather than providing a broad overview of published literature, the goal of this review was to identify key findings and gaps in the discourse surrounding this topic, specifically highlighting the imperative for educational frameworks that incorporate SD principles. Given the limited scope of articles published in the field of SD, this review underscores the urgent necessity of integrating science diplomacy (SD) into both the literature and medical education—positioning it as a fundamental component in preparing health professionals to navigate the complexities of global health.

By equipping future healthcare leaders with the necessary skills to engage in global health diplomacy, we can better address the intricate challenges posed by contemporary health issues (Jogerst et al., 2015; Koehn & Swick, 2006). Incorporating these principles into educational programs can enhance students' capabilities to collaborate effectively with international partners and engage in meaningful global health diplomacy (Katz et al., 2011). Furthermore, the shift towards emphasizing transnational competence is essential. This transition requires educational institutions to rethink traditional models of cultural competence and develop curricula that address the complexities of global health, including the influence of policy and diplomacy on health outcomes (Wit & Altbach, 2020).

Ultimately, the review highlights that effective health diplomacy is contingent upon robust collaborative networks among nations, particularly during health crises such as the COVID-19 pandemic (Lee, 2021). Integrating SD into medical training can empower future healthcare professionals to engage more meaningfully within these networks. Additionally, recognizing SD as a critical element of foreign policy is vital for tackling pressing global health issues; thus, medical education must prepare students to advocate for and implement health policies that leverage scientific collaboration. In summary, these insights emphasize the pressing need for educational reform that weaves science diplomacy into the fabric of medical education, ensuring that future health professionals are well-equipped to engage effectively in an interconnected world and contribute to resolving complex global health challenges.

4.3. Proposed Solutions

To ensure the long-term growth and impact of science diplomacy, it is essential to address the current gaps in both research and practice. Establishing a shared vocabulary, building comprehensive databases of case studies, and fostering cross-regional collaboration are necessary steps. Greater academic engagement, coupled with policy support, can help bridge the divide between practice and theory.

Additionally, formalizing science diplomacy education—through integrated curricula and interdisciplinary programs—will strengthen the next generation of science diplomats. Efforts to align science diplomacy with global challenges such as climate change, pandemic preparedness, and biodiversity loss will also provide opportunities for expanding its relevance and impact.

One of the key solutions is embedding science diplomacy within broader science policy and international relations courses (Paradis & Whitehead, 2018). These modules expose students to diplomatic processes alongside scientific methods, cultivating an understanding of how scientific knowledge can inform policy decisions at national and global levels. Universities are increasingly adopting experiential learning techniques, such as role-playing simulations of international negotiations (e.g., climate summits or health diplomacy scenarios), to allow students to practice mediating between scientific evidence and political interests. These activities encourage critical thinking and negotiation skills, preparing students to operate effectively in complex diplomatic environments where science plays a central role.

Medical curricula incorporating SD typically align with areas like global health governance and pandemic response, where understanding cross-border collaboration is crucial. For instance, courses on vaccine diplomacy explore how scientific innovations, such as COVID-19 vaccines, intersect with geopolitical considerations, soft power, and equity in global health access. Additionally, frameworks like the United Nations Sustainable Development Goals (SDGs) offer context for integrating SD within medical education, highlighting the importance of public health as part of broader sustainability efforts.

The challenge of integrating SD education lies in designing curricula that are both specialized and adaptable to various academic programs. To address this, universities are experimenting with modular course structures (Mauduit & Soler, 2020). For example, SD principles are embedded into environmental health programs, medical ethics courses, and public health curricula, ensuring students from diverse backgrounds gain exposure to diplomacy in contexts relevant to their fields. These cross-cutting modules make it possible to adapt SD education to different student cohorts—whether undergraduates, medical students, or professionals pursuing advanced degrees.

To foster transdisciplinary competencies, some programs encourage collaborations between faculties of science, medicine, and international relations. This collaborative approach enables students to gain insights into multiple perspectives—scientific, diplomatic, and policy-oriented—ensuring they are equipped to manage the complexities of global health issues. Institutions are also working to formalize partnerships with international organizations, research institutes, and think tanks to provide students with hands-on experience in science diplomacy practice.

Integrating science diplomacy (SD) into medical curricula is becoming a strategic response to the growing demand for interdisciplinary skills that address global challenges such as pandemics, climate change, and public health inequities (Wu, 2023). Current approaches focus on developing educational models that emphasize cross-sector collaboration, real-world problem solving, and transdisciplinary knowledge. However, the field remains in its formative stages, and efforts to institutionalize SD into higher education, particularly in medical programs, are still evolving.

5. CONCLUSION

The review highlights the importance of science diplomacy (SD) in tackling global challenges like pandemics, climate change, and health inequities, exemplified by initiatives such as vaccine diplomacy. However, the lack of systematic frameworks and consistent terminology limits SD's growth as a robust discipline, underscoring the need for targeted research to solidify its role in global health.

In terms of education, the review highlights a marked absence of SD-focused models within medical curricula. While related concepts such as global health governance and pandemic response appear sporadically, the explicit integration of SD principles is rare. This lack of focus reveals a broader challenge: the absence of standardized curricula and competency models that equip healthcare professionals with the skills needed to navigate the intersection of health, policy, and diplomacy. Without these educational structures, healthcare

leaders are left inadequately prepared to address complex global challenges that increasingly require diplomatic solutions.

To address these gaps, the review proposes embedding SD into medical education through interdisciplinary coursework, modular curriculum designs, and hands-on learning experiences, such as simulations of international negotiations. These approaches align with broader educational efforts in science policy and initiatives like the United Nations Sustainable Development Goals (SDGs). Yet, significant obstacles remain, including limited institutional support, inadequate collaboration across sectors, and a lack of representation from underrepresented geopolitical regions. Closing these gaps will demand a concerted effort from universities, policymakers, and international organizations to institutionalize SD education and establish it as a fundamental component of preparing healthcare professionals for global leadership.

Science diplomacy (SD) is poised to play a pivotal role in addressing the multifaceted challenges of the 21st century, but it remains an underexplored field within academic research and practical application. Its future success depends on building a cohesive research base, expanding inclusive participation, and developing standardized educational frameworks. Strengthening the institutional foundations of the field will enable science diplomacy to move beyond ad hoc initiatives and become a key instrument for addressing the scientific and policy needs of the 21st century.

Moreover, the development of standardized educational frameworks is vital for creating a consistent approach to SD training across disciplines. By establishing core competencies and learning outcomes for science diplomacy education, institutions can ensure that graduates possess the necessary skills to navigate complex international environments. Such frameworks can be supported by national and international policies that encourage universities to incorporate SD into their curricula as part of broader educational reforms aimed at promoting interdisciplinary collaboration.

To maximize the impact of science diplomacy, it is crucial to align educational efforts with pressing global issues such as health crises, environmental sustainability, and technological advancements. Emphasizing these connections will not only enhance the relevance of SD in medical and scientific education but also inspire a new generation of professionals to engage proactively in shaping policy outcomes. This alignment can facilitate a more integrated approach to problem-solving that recognizes the interconnectedness of scientific inquiry and diplomatic engagement.

The time is ripe for initiating discussions among educators and policymakers on how to standardize and streamline science diplomacy curricula. By aligning SD training with contemporary healthcare challenges and global priorities, there is an opportunity to create robust educational frameworks that foster meaningful international collaboration. Emphasizing practical skills, ethical engagement, and shared learning will ensure that the next generation of science diplomats is well-equipped to navigate complex global landscapes and contribute positively to the future of international science and health diplomacy.

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