Humanities & Social Sciences Communications

ARTICLE

https://doi.org/10.1057/s41599-025-05947-w OPEN

# Science diplomacy in small states: a case study of global players' engagement in Slovakia

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This paper examines the science diplomacy strategies employed in Slovakia by three major global players from America, Europe, and Asia: the United States, France, and China. Through a comparative analysis, it assesses the impact of these countries' efforts on Slovakia's scientific and technological development, as well as on human capital outflow, commonly referred to as 'brain drain'. The study adopts a qualitative methodology, combining secondary sources with key informant interviews conducted with embassy representatives involved in science diplomacy initiatives. The findings highlight the distinctive approaches of each country: the United States focuses on educational exchanges and fostering entrepreneurship; France emphasizes academic cooperation through EU research frameworks; and China prioritizes investment in technological partnerships. The research also reveals the challenges Slovakia faces in leveraging these international collaborations to address its brain drain problem. While these initiatives strengthen bilateral relations and support capacity-building, they often fail to directly address talent retention within Slovakia. This study sheds light on the strategic role that science diplomacy plays in shaping the scientific landscape and the international standing of smaller states, such as Slovakia. It offers policymakers and scholars valuable insights into the complexities of science diplomacy and its broader implications for global cooperation and development.

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## Introduction

Science diplomacy has emerged as a significant area of interest in international relations, particularly for large nations seeking to expand their global influence. In recent years, many of these countries have adopted science diplomacy strategies to strengthen their soft power and enhance international relations. Recognizing the strategic value of science, technology, and education in achieving foreign policy objectives, they have increasingly invested in dedicated Science diplomacy activities, often distinguishing them from traditional cultural diplomacy (Olšáková 2023). In this context, large countries are characterized by substantial population size, strong economic power, and extensive scientific and technological capabilities. These attributes enable them to implement science diplomacy strategies that project their interests globally. In contrast, small countries, with limited populations and economic power, often become arenas for the science diplomacy initiatives of larger nations (Gluckman et al. 2012).

Slovakia, as a small country located in Central Europe, provides an interesting case study for the evaluation of large nations' science diplomacy policies. The country has made significant progress in developing its science, technology, and education sectors since gaining independence in 1993. It has a well-established system of universities, research institutes, and innovation centers, and has been investing in promoting scientific research and innovation. As a member of the European Union, Slovakia has access to various funding programs to support research and development activities. Despite these efforts, Slovakia still faces significant challenges, including limited research funding, which adversely affects the quality of education and research and contributes to a substantial brain drain (Cedzová et al. 2020). Therefore, the country seeks collaboration with global players to strengthen its science, technology, and education landscape and improve its competitiveness in the global arena.

However, the science diplomacy of large countries may not always align with Slovakia's priorities and interests. Hence, it is essential to evaluate the science diplomacy strategies of different countries operating in Slovakia to understand their goals and motivations, as well as the impact of their initiatives on the country's science, technology, and education landscape, including its ability to retain talent. This evaluation of science diplomacy policies in Slovakia can provide insights into the opportunities and challenges for small countries in collaborating with larger nations to promote scientific research and innovation.

Slovakia serves as a representative and instructive case study in the field of science diplomacy. As a small state in Central Europe, it shares key structural features with other countries in the region —such as limited R&D capacity, high outbound student mobility, and strong reliance on EU research funding. Its position within the Visegrad Group (V4), alongside Czechia, Poland, and Hungary, reflects a common historical trajectory and comparable institutional challenges. Unlike some neighboring countries, Slovakia lacks a formal science diplomacy framework, which reinforces its position as a recipient of externally driven initiatives. At the same time, Slovakia's geographic centrality and openness to external engagement make it an ideal site for examining how major global players apply distinct science diplomacy strategies in a smaller, research-dependent EU member state. Insights from this case may thus hold broader relevance for understanding asymmetrical science diplomacy relations in the wider Central and Eastern European context.

One particularly poignant aspect of Slovakia's science diplomacy story is the challenge of human capital outflow. The OECD report of 2022 highlights that while most OECD countries are net importers of students, Slovakia, along with Colombia and Luxembourg, is a net exporter, with less than 0.5 internationally mobile students—those studying abroad outside their country of origin—per national student (OECD 2022). Slovakia has one of the highest outbound mobility ratios in Europe, with 22.3% of tertiary students studying abroad in 2020 (UNESCO 2020). While Slovak students go abroad to gain knowledge and skills, the issue lies in the fact but that most do not return home after they finish their studies (Cedzová et al. 2020). This trend has a detrimental effect on the country's economy.

Brain drain is not a problem unique to Slovakia, many small nations grapple with the phenomenon as their skilled workforce seeks opportunities abroad. This issue is exacerbated when major global players enter the scene, attracting talent and expertise. Understanding how science diplomacy impacts human capital retention and outflow in Slovakia contributes to a broader conversation on the implications of global collaboration for the scientific workforce of smaller states.

The current paper aims to assess the science diplomacy endeavors of prominent international actors in America, Europe and Asia, namely the United States, France and China, in Slovakia, from a comparative perspective. Hence, the focus of the paper lies in analyzing the activities of the three countries in Slovakia, not Slovakia's science diplomacy actions as such. These countries were selected intentionally, based on both theoretical and practical considerations. The selection reflects their global importance in science diplomacy and incorporates players that are geographically, politically, and culturally diverse. Each embodies a distinct model of science diplomacy and has shown strong engagement in scientific collaboration with Slovakia, providing a solid basis for analysis. Furthermore, the authors have utilized their personal connections at the embassies in Bratislava to gather deeper insights. A major focal point is to evaluate whether the science diplomacy policies of these global players exacerbate the problem of brain drain in Slovakia or potentially hold the promise of alleviating it. Despite selecting the three above-mentioned countries, the authors of the paper are fully aware of the prominence of other global science diplomacy actors, such as the United Kingdom, Germany, or Israel. Including them in the analysis is contemplated for the authors' further academic endeavors.

The paper is organized as follows. In the second section, we discuss the methodology used in the study. In the third section, we employ a comprehensive literature review to characterize the concept of science diplomacy and the way the United States (U.S.), France and China organize and perform their science diplomacy. Next, we discuss the research results linked to the science diplomacy activities of the selected global players in Slovakia.

## Methodology

The methodology employed in this paper is qualitative, designed to explore and analyze the science diplomacy strategies of the U.S., France, and China in Slovakia. A qualitative approach is particularly suitable for examining complex social phenomena, as it enables the collection of rich, detailed data that quantitative methods cannot capture.

**Data collection**. Key Informant Interviews (KIIs) were the primary method for collecting first-hand data. KIIs are particularly relevant to our research because their purpose is "to collect information from a wide range of people—including community leaders, professionals, or residents—who have first-hand knowledge about the community" (UCLA Center for Health Policy Research 2023). Hence, the information provided within the interviews can be viewed as highly accurate and up-to-date.

**Table 1 Key Structured Interview Questions for Embassy Representatives.**

| Question | Purpose |
|---|---|
| Does your country explicitly use science diplomacy in its foreign affairs? | Understand whether science diplomacy is a formal component of the country's foreign policy. |
| Who are the main stakeholders in science diplomacy of your country in Slovakia? | Identify the key actors involved in implementing science diplomacy in Slovakia. |
| What are the primary goals of science diplomacy of your country in Slovakia? | Explore the strategic objectives behind the Science Diplomacy efforts. |

Moreover, they allow researchers to obtain high-quality data within a relatively short period of time in a cost-effective manner, being quicker and less expensive than large-scale surveys (Marshall 1996).

However, KIIs come with certain drawbacks that need careful management. One significant downside is selection bias, which occurs when informants are not appropriately chosen, leading to skewed data that does not accurately represent the broader population or issue being studied. Interviewer bias is another concern, where the interviewer's preconceived notions can influence the data collection process. The qualitative and often subjective nature of KIIs also raises issues of generalizability, as findings may not apply directly to a larger population. The reliability of the data can be compromised if the interviewer fails to maintain neutrality or if informants provide inaccurate information. Additionally, high-profile or busy informants can be difficult to reach, limiting the breadth of perspectives obtained from interviews (Akhter 2022).

In our study, we took several steps to mitigate these risks and enhance the reliability and validity of our findings. To address selection bias, we directly approached relevant representatives from the U.S. (respondent A), Chinese (respondent B), and French (respondent C) embassies in Bratislava. These representatives are central figures in implementing their respective countries' science diplomacy policies in Slovakia, making them clearly identifiable and ensuring that our key informants were both knowledgeable and relevant to our research topic.

To mitigate interviewer bias, we maintained a neutral stance and used semi-structured interviews that allowed for open-ended responses, enabling participants to express their views without being led. This approach helped in collecting data that reflects the informants' true perspectives and reduced the likelihood of interviewer bias influencing the results.

Regarding generalizability and reliability of the data, we integrated the insights from the KIIs with available information from the internet and the websites of embassies, along with relevant policy documents and academic literature. This triangulation of data sources provided a comprehensive analysis of the science diplomacy strategies of the U.S., France, and China in Slovakia, enhancing the validity of our findings.

Additionally, the interviews were conducted in English, both by email and in-person, depending on the availability and preference of the interviewees. Respondents A and B preferred to reply by email, while respondent C accepted a face-to-face interview that lasted one hour and was transcribed. Respondent A was the Cultural Affairs Officer at the U.S. Embassy in Bratislava; Respondent B was a policy officer in the political section of the Chinese Embassy; and Respondent C served as the Attaché for scientific and academic cooperation at the French Embassy in Bratislava, working in coordination with the French Institute. While we recognize the limitations of this approach, such as potential asymmetry in the depth and detail of the interviews, we openly accepted this trade-off as it accommodated the preferences of high-profile informants and ensured their participation. This flexibility enriched the diversity of the data collected, providing a broader range of insights into the science diplomacy strategies of the respective countries.

We recognize that Slovak stakeholders were not included in this interview round, as the study focuses on how foreign actors practice science diplomacy in Slovakia. Future research may incorporate perspectives from Slovak institutions and scholars to provide a more comprehensive understanding of both bilateral engagement and domestic science diplomacy dynamics.

The interview questions aimed to determine whether science diplomacy is a formal component of the country's foreign policy, identify the key actors involved in implementing science diplomacy in Slovakia, and explore the strategic objectives behind these efforts, both in the short term and the long term. The main structured questions used during the interviews are outlined in Table 1.

**Analytical framework**. The study employed thematic analysis to interpret the collected data. This method involves identifying, analyzing, and reporting patterns or themes within the data. The analysis was guided by the heuristic framework developed by Flink adn Schreiterer (2010), which categorizes science diplomacy into three key dimensions: *access*, *promotion*, and *influence*. These dimensions specifically represent:

–*Access*: how major powers leverage their science diplomacy to gain entry into Slovakia's research environment, including access to local expertise, research infrastructure, and potential collaborations. This dimension includes the identification of initiatives aimed at establishing partnerships, sharing research outputs, or gaining insights into the Slovak academic ecosystem.

–*Promotion*: efforts of these countries to highlight their R&D achievements and enhance their scientific reputation within Slovakia. Promotional activities may include showcasing technological innovation, hosting collaborative events, or offering scholarships and fellowships to Slovak students and researchers.

–*Influence:* how science diplomacy is employed to shape public opinion, engage policymakers, or foster support for the sponsoring country's broader geopolitical objectives. This dimension examines initiatives targeting Slovak decision-makers or the general public to promote norms and values tied to the scientific and diplomatic priorities of the global players (Flink and Schreiterer 2010).

While this framework remains a useful analytical tool, recent scholarship has highlighted the need for more flexible and context-sensitive approaches to science diplomacy. Scholars have noted that rigid typologies may oversimplify complex and overlapping motivations (Ruffini 2020; Copeland 2016; American Association for the Advancement of Science 2025). Therefore, we apply Flink and Schreiterer's model as a guiding lens rather than a fixed categorization, acknowledging the hybrid strategies employed by different actors in practice.

The framework offered a structured lens for categorizing and comparing the science diplomacy strategies of the U.S., France, and China, enabling a systematic exploration of how these strategies align with Slovakia's strategic objectives and the broader

dynamics of science diplomacy in small states. Through a robust qualitative research methodology, which incorporated detailed insights from embassy representatives and mitigated risks associated with key informant interviews, the study provides a comprehensive analysis of the practice of science diplomacy and its impact on Slovakia's scientific and educational landscape.

## Literature review

### Science diplomacy—conceptual issues

*Definition and coverage of science diplomacy*. Science diplomacy is an emerging field of study at the intersection of international relations and science policy, which has received only limited attention from scholars in the Central European region despite its increasing importance. It is a concept that involves the use of science as a means of fostering cooperation and improving relations between nations. Its paramount relevance to addressing global challenges was emphasized at the Madrid Conference in 2018. It was further agreed that science diplomacy is often not exploited to its full potential (Science for Diplomacy for Addressing Global Challenges 2019).

The available literature investigates the concept of science diplomacy from various perspectives. Some authors analyze science diplomacy in a regional cluster, while others attempt to conceptualize it. Other authors focus exclusively on the science diplomacy of a particular country.

Diplomacy and its individual dimensions are subject to geopolitical developments (Goda and Čiefová 2019), responding to the dynamics of the world. As a result, new branches of diplomacy can emerge, requiring conceptualization. Despite the long history of the relationship between science and diplomacy, the term 'science diplomacy' is a phenomenon of the 21st century. Since then, there have been numerous efforts to define science diplomacy, which have produced different typologies of operations and motivations associated with it (Turekian 2018).

Perhaps the most well-known and cited categorization is the one proposed by the Royal Society of London and the American Association for the Advancement of Science (AAAS). They define science diplomacy in three ways: (1) "science in diplomacy", where scientific advice is used to inform foreign policy; (2) "diplomacy for science", in which political capital is used to advance scientific research; and (3) "science for diplomacy", whereby scientific cooperation is used to improve international relations (The Royal Society 2010; American Association for the Advancement of Science 2009).

Within the framework of the Madrid Declaration on Science Diplomacy, science diplomacy is viewed as "practices at the intersection of science, technology and foreign policy" (Science for Diplomacy for Addressing Global Challenges 2019). According to Su and Mayer (2018), science diplomacy can be defined "as a set of practices that open up sustained channels of communication and cooperation for the main purpose of producing objective knowledge." The authors emphasize its importance for trust-building in international relations.

Turchetti and Lalli (2020) propose an advanced concept of science diplomacy, termed "Science Diplomacy 2.0," which emphasizes a stronger focus on addressing societal and global challenges. This approach involves creating tools to assist policy-makers in making informed decisions among various collaborative research options. A key tool in this framework is the *responsible innovation observatory*, which gathers and integrates data from diverse disciplines using a linked-data, multi-layered method. The objective is to analyze and prioritize research areas either regionally, based on local societal needs, or globally, in response to broader challenges (Turchetti and Lalli 2020).

Ruffini (2020) describes science diplomacy as a set of practices where international relations and foreign policy intersect with science and technology. This field is intricate and multifaceted, characterized by its dual nature, which intertwines scientific pursuits with diplomatic objectives. Equally significant is the characterization of science diplomacy as a scientific discipline situated at the intersection of international relations and science (Arnaldi et al. 2021). Science diplomacy is also viewed as a subfield of public diplomacy and a source of soft power (Copeland 2011). Navigating this complexity requires a subtle understanding of its potential challenges.

One of the core characteristics of science diplomacy is its capacity to create a neutral space for dialogue and cooperation. The scientific community operates according to widely accepted social rules and values, prioritizing knowledge and understanding above political or ethnic considerations. This enables collaboration regardless of broader political tensions. However, science is not immune to drawbacks, including chauvinism, intense competition, and reputation-driven rivalries. Instances of misconduct or involvement with dubious political or business interests further underscore its complexity (Flink 2020).

Building on these critiques, a growing body of scholarship has begun to challenge the normative assumptions underpinning science diplomacy. Hussein and Awad (2024), for example, critique Western-led initiatives for perpetuating structural inequalities and implicit biases, particularly in their engagement with smaller or less powerful states. They argue that despite promoting mutual benefit, science diplomacy can reproduce hierarchical relationships and constrain the agency of recipient countries. This critique is particularly relevant in assessing Slovakia's position within global science diplomacy networks and highlights the need to examine both the intended and unintended consequences of external engagement.

Science diplomacy is often conflated with international scientific cooperation, a mistake that has caused confusion (Copeland 2016). Unlike international science cooperation, science diplomacy explicitly involves state interests, exhibiting a dual nature of cooperation and competition. This competition extends not only to global players but also among European Union member states (Flink and Schreiterer 2010).

A similar ambiguity surrounds the role of student mobility. While often treated as part of cultural or educational diplomacy, mobility programs may fall within the scope of science diplomacy when they are used to foster bilateral research collaboration, scientific training, or foreign policy objectives—as is the case with initiatives such as Fulbright, Erasmus+, or Chinese government scholarships.

Flink (2020) raises two key criticisms of science diplomacy. First, there is uncertainty about how science benefits if it becomes an instrument of foreign policy. Second, it questions whether foreign policy truly benefits from science diplomacy if an overly idealized view of science is adopted.

International scientific relations often operate within one of two paradigms: *positive-sum game diplomacy*, which seeks shared global benefits through cooperation; or *zero-sum game diplomacy*, which yields economic or reputational advantages for one side at the expense of another. It is essential, therefore, to distinguish between using science as a collaborative foreign policy objective and using it as a strategic tool for geopolitical competition (Penca 2018).

Science diplomacy can be implemented in several ways. One approach involves promoting a nation's scientific research and culture to build relationships and cooperation with other countries. This includes supporting the international mobility of scientists, fostering research and innovation, and collaborating with foreign institutions on projects. Another approach uses

science to address global challenges and promote international cooperation, such as participating in discussions on climate change or sustainability.

The approach to science diplomacy of the countries in focus of this study involves "science for diplomacy" and "diplomacy in science." The French government, for instance, supports the international mobility of French scientists, promotes research and innovation abroad, and collaborates with foreign institutions. France also addresses global challenges through science diplomacy by participating in international negotiations, such as those on climate change.

Science diplomacy plays a vital role not only in addressing critical global issues but also in easing international political tensions, particularly when standard diplomatic avenues are ineffective or unavailable. As highlighted by Copeland, the impartial and non-partisan nature of scientific language significantly contributes to this process. An example of this was observed during the Cuban Missile Crisis in the Cold War era, where, despite heightened tensions, Soviet and American scientists continued their joint efforts in various research fields such as polar studies, atmospheric science, healthcare, deep-sea exploration, and the management of radioactive waste. More recently, amidst the disputes over Crimea and Eastern Ukraine, collaboration between U.S. and Russian scientists persisted, especially in Arctic research, operations on the International Space Station, and in crucial international negotiations like the 2015 Iran nuclear deal and the 2013 Syrian chemical weapons disarmament. (Copeland 2016) Yet, it is easier to confirm the notion that good diplomatic relations between countries facilitate effective research cooperation, it's more challenging to demonstrate that international research and innovation collaboration has significantly improved relations between rival countries (Penca 2018).

Governments worldwide pursue similar science diplomacy agendas, such as Japan's "Science and Technology Diplomacy" program (2007), Germany's "Außenwissenschaftspolitik" (2008), and Denmark's "Techplomacy" (2017) (Kunkel 2021).

A survey conducted within the Central European Initiative (CEI), including Slovakia, identified motivations for investing in science diplomacy. These include:

- influencing decision-makers, economic leaders, and public opinion in other countries;
- accessing research findings, researchers, and resources abroad to enhance national innovation capacity;
- promoting national R&D achievements as part of global marketing strategies.

In most countries involved in the study, training of both diplomats and scientists is critical, as is networking between the diplomatic and scientific communities (Arnaldi and Tessarolo 2019).

Similarly, science diplomacy of the region of Central, Eastern and South-eastern Europe was investigated, categorizing scientific cooperation into two clusters: Southern and South-eastern Europe, and Central and Eastern Europe. Slovakia falls into the latter, alongside Belarus, Bulgaria, Czechia, Hungary, Moldova, and Poland (Arnaldi et al. 2021).

Fikkers and Horvat (2014) identify reasons for bilateral Science, Technology and Innovation (STI) agreements, dividing them into *narrow* and *broad* paradigms. The Broad paradigm aligns with science diplomacy, including objectives such as public diplomacy, transforming diplomatic relationships, and addressing security concerns.

In relation to security concerns, another aspect of science diplomacy emerges—the increasing role of artificial intelligence (AI). Not surprisingly, AI has already started altering science diplomacy practices, motivating a number of scholars to analyze these impacts, challenges and possible threats. For example, not only the ethical implications of AI have been explored, but also its capacity to enhance diplomatic efforts, thereby improving responses to global challenges (Varela 2024). Konovalova's investigation is twofold, as she considers both directions—AI for diplomacy and diplomacy for AI. She concludes that digital skills and the integration of AI can strengthen diplomatic personnel and improve the effectiveness of diplomatic tools (Konovalova 2023). Furthermore, the potential of AI as a valuable instrument in science diplomacy is highlighted, particularly for addressing shared global challenges and fostering international cooperation (Baig et al. 2024).

*Actors of science diplomacy*. Science diplomacy can be considered to be a specific field of diplomacy and foreign policy. Since it often intersects with goals in other domains, the roles and backgrounds of science diplomacy actors may be diverse. It is frequently distinguished between states and non-state actors (Reinhardt 2021). Hence, science diplomacy can, for instance, be a task of career diplomats, scientists, or politicians, as well as science counselors, advisors or experts (Szkarłat 2020; Reinhardt 2021). It may also involve funding agencies, civil society organizations, the media, or the private sector (Sabzalieva et al., 2021).

Some authors focus primarily on states as the primary actors in science diplomacy, though they do not underestimate the role of non-state actors. Bertelsen (2024) considers the state to be a key actor due to its ability to utilise science for foreign policy purposes. Szkarłat (2020) adds that the most advanced countries in terms of their experience and implementation of science diplomacy are rich, industrialized states. While states are perceived as powerful actors, many non-state actors also possess significant financial resources and intellectual capacities. States and non-state actors can both compete and cooperate. Moreover, non-state actors' activities are often materially supported by states, utilised as tools, or tolerated within diplomatic frameworks (Bertelsen 2024). This distinction is relevant to our research, as it predominantly involves states but also incorporates stakeholders such as the U.S. Fulbright Program.

Moomaw (2018) addresses the question of whether successful science diplomacy requires professional diplomats to acquire specific scientific knowledge, thus becoming scientist-diplomats, or whether scientists should refocus on diplomacy, becoming diplomat-scientists. His research highlights important policy implications, concluding that successful science diplomacy "requires negotiators to have a sound understanding of underlying science" and "input from scientists who understand and can contribute to the policy process". Therefore, diplomacy should not ignore scientific input, while science alone is unlikely to create a significant policy impact (Moomaw 2018).

Countries can also conduct science diplomacy through their membership in international organizations or fora. Overlapping science-, health-, or environment-related objectives may lead to joint approaches for tackling shared challenges. An example is the emergence of the All-Atlantic Ocean Research Alliance. Another example is the International Atomic Energy Agency, which has a long history of integrating diplomatic activities into its scientific initiatives (Adamson 2021).

Another type of science diplomacy actor is research institutes, particularly those focusing on international relations or the economy of specific geographical areas. These institutes aim to facilitate or strengthen diplomatic ties with countries in their focus regions. Other actors include universities, non-profit partnerships (Reinhardt 2021), and even foundations. Charities,

especially in the U.S., often fund research collaborations and educational exchanges, enhancing science diplomacy efforts (Bertelsen 2024).

**Science diplomacy of the U.S., France, and China**. Prior to the beginning of the new millennium, not many countries were prepared to purposefully address and engage with S&T issues in their foreign policy or to compete for global talent. Since then, there has been a surge in international scientific strategies, which have had a significant impact on international relations (Flink and Schreiterer 2010). While most large countries since the 2000s have formally institutionalized science and technology diplomacy initiatives, their objectives differ considerably. Flink and Schreiterer (2010) developed a typology of national approaches towards science diplomacy. They found that for the U.S.'s science diplomacy, political influence plays a central role, while countries like France, Switzerland, Germany, and Japan mainly focus on gaining access to promising markets and developments in R&D, as well as promoting their science, technology, research, and higher education in the global marketplace.

As Copeland recalls, the capacity for science diplomacy varies significantly among countries, primarily influenced by their size, wealth, and level of development. Major powers like the U.S., the UK, and France have the resources and infrastructure to engage in a broad range of science diplomacy activities. In contrast, smaller nations tend to specialize in areas that align with their specific strengths and needs. For instance, Switzerland focuses on commercial technological innovation, while New Zealand concentrates on issues related to agricultural greenhouse gas emissions, biosecurity, and phytosanitation. Generally, less developed countries face challenges in engaging effectively in science diplomacy due to their limited S&T capacities (Copeland 2016).

According to the Secretary of the Indian Department of Biotechnology, the Western countries "have seen science and education as instruments of foreign policy, of income and of brain-gain" (UNESCO 2015). This perception represents a significant challenge for emerging economies, which often struggle with brain drain. Consequently, there is an inherent tension between developed countries using science diplomacy to enhance their international competitiveness and those that serve as traditional exporters of scientific talent.

In the world's leading scientific power, the U.S., various institutions address different aspects of S&T policy, coordinated by the White House Office for S&T Policy, which has no dedicated budget for science diplomacy. According to Flink and Schreiterer (2010), the institutional setting makes the U.S. international S&T policy "highly fragmented, imponderable and inward-looking". Knudsen (2021) attributes the relatively limited official science diplomacy initiatives of the U.S., incommensurate with its economic and geopolitical clout, to the natural appeal of the U.S. research ecosystem. However, the U.S. runs one of the most widely recognized and prestigious scholarship programs in the world, established in 1946. The Fulbright Scholar Program annually enables 800 U.S. scholars to go abroad and 900 foreign scholars to come to the United States, contributing to mutual understanding and addressing common societal challenges.

France is another major player in science diplomacy, operating one of the largest science diplomacy networks, with 160 embassies and substantial resources. In 2009, France adopted a *National Strategy for Research and Innovation*, enshrined in 2013 and presented every five years by the government to Parliament. The French approach to science diplomacy was officially laid out in the 2013 *Science Diplomacy for France* report.

Science diplomacy is seen as an important tool for stimulating development, maintaining France's leadership, driving innovation, and mobilizing global networks for French (and European) interests. The government aims to increase interaction between France's scientific community and its diplomatic network to:

> Support the status of French researchers and companies in international competition;
> Align scientific efforts with foreign policy objectives;
> Raise awareness among researchers of development issues and build the Global South's scientific capabilities (Ministry for Europe and Foreign Affairs of France 2013).

To increase France's attractiveness in research and innovation, the Ministry of Foreign Affairs, together with the Ministry for Higher Education and Research, identified five priorities:

1. Enhance the perception of the French research system abroad;
2. Improve admission conditions and facilities for foreign researchers in France;
3. Enhance France's science and technology image in the general public's eyes by promoting a culture of science and technology;
4. Encourage large-scale research facilities to be established in France and access by French researchers to such facilities abroad;
5. Contribute to internationalizing the French social sciences and humanities sector.

Responsibilities for science diplomacy are shared between the Ministry for Europe and Foreign Affairs, individual institutes and universities, and French National Research Agency (Flink and Schreiterer 2010). An important tool is the network of French Research Institutes Abroad (UMIFRE), active in 34 countries, focusing primarily on the Mediterranean and the Middle East (Knudsen 2021).

Flink and Schreiterer (2010) describe France's science diplomacy as a matrix with three dimensions, where different world regions or countries are represented on one axis, and agencies and their respective programs are represented on the other two. French science attachés are seconded from different institutional stakeholders and administer significant funds through a variety of programs. Most of the funds are allocated for scholarships for postgraduate studies or research stays in France. Except for agri-food and health security in Sub-Saharan Africa, France does not set as an objective of its science diplomacy the addressing of global challenges.

Science and technology have traditionally been central to Chinese foreign policy, particularly in its interactions with the West, with the primary aim of modernizing China's economy. In the late 20th century, China was a knowledge importer with weak domestic scientific capabilities and was unable to engage in science diplomacy as developed nations did. However, market reforms introduced in the late 1970s spurred decades of unprecedented economic growth and technological advancement. Today, China has reached or exceeded technological parity with developed countries in certain areas, enabling it to engage in science diplomacy as a key global actor.

Following the Western example, in the same way as with the concepts of soft power and public diplomacy, China has recently adopted the idea of science diplomacy and tried to integrate it into its own policy approaches to international relations. While China already possesses the capability to pursue science diplomacy as a means of projecting soft power, it has not yet turned it into a policy action. However, the importance of science diplomacy is explicitly recognized in official policy documents. In the National 13th Five-Year Plan for S&T Innovation the need for fostering the systemic design of national science and technology

**Table 2 Comparative indicators of scientific and technological capacity and talent mobility in Slovakia and comparator Central and East European countries (2022).**

| Country | R&D expenditure (% of GDP) | Researchers (% of total employment) | Tertiary students studying abroad (%) | Population living in OECD countries (% of total population) in 2021 |
|---|---|---|---|---|
| Slovakia | 0.98 | 0.86 | 21.60 | 7.1 |
| Czechia | 1.89 | 1.68 | 3.55 | 1.8 |
| Hungary | 1.39 | 1.32 | 6.5 | 5.8 |
| Poland | 1.45 | 1.13 | 1.82 | 6.5 |
| Romania | 0.46 | 0.43 | 5.70 | 18.4 |
| Bulgaria | 0.75 | 0.91 | 8.88 | 13.0 |

Eurostat (2024), UNESCO (2024), OECD (2024).

diplomacy and cooperation is stated, outlining its goals - to "deepen intergovernmental scientific and technological cooperation, classify and formulate country-specific strategies, enrich the scientific and technological content of new great power relationships, promote the establishment of innovative strategic partnerships with developed countries in science and technology, build an innovative community of mutually beneficial cooperation with neighboring countries, and extending the framework of the Science and Technology Partnership Program for developing countries" (PRC State Council, 2016).

According to Freeman (2019), China's science diplomacy is essentially an extension of its international science cooperation policies, and it is questionable whether science diplomacy has been fully developed as a coherent policy. Even its flagship developmental strategy—the Belt and Road Initiative—incorporates science and technology but has not explicitly framed science diplomacy as a policy tool. Fedasiuk et al. (2021) posit that Chinese S&T diplomats, stationed across 52 countries, primarily focus on monitoring technological developments, identifying investment opportunities for Chinese firms, and supporting the *Made in China 2025* strategy. Their efforts often prioritize biotechnology and artificial intelligence and focus on technologically advanced countries like the U.S., Russia, the UK, and Japan.

China's commitment to *science diplomacy* was further institutionalized with the adoption of a *Science and Technology Progress Law* in March 2023 (Mok 2023). This law forms part of a broader policy effort to increase international scientific cooperation and enhance China's global influence through science and technology. China's diplomatic missions are central to implementing this agenda. Reflecting this national strategy, the Chinese Embassy in Slovakia promotes technological collaboration and innovation as part of its science diplomacy outreach.

China's approach to science diplomacy is also linked to activities in the Arctic and Antarctica, particularly through the *Polar Silk Road*. Such ambitions have been incorporated into the *14th Five-Year Plan* (Lanteigne 2021). China's presence in the Arctic region is often considered suspicious. Nevertheless, Chinese scientists have managed to establish considerable networks and develop collaborations (Su and Mayer 2018). Furthermore, Confucius Institutes, have faced scrutiny for their potential role in espionage and influence operations, raising questions about the broader implications of Chinese science diplomacy.

The selection of the United States, France, and China as case studies reflects their contrasting approaches to science diplomacy and distinctive roles in global and regional contexts. The U.S. uses a "science for diplomacy" model, leveraging scientific collaboration to achieve broader foreign policy aims. France exemplifies a "diplomacy for science" approach, promoting its institutions and influence in the European research landscape. China, as an emerging science diplomacy actor, combines technology access initiatives with strategic partnerships in Central and Eastern Europe, offering a unique perspective.

## Research findings and discussion

Before analyzing the impact of global science diplomacy initiatives, it is useful to consider Slovakia's relative standing in the region in terms of its conditions for science, technology, and talent retention. Table 2 presents comparative data on Slovakia and other Central and East European (CEE) countries, illustrating the scientific and economic constraints that shape Slovakia's engagement with external science diplomacy actors.

As shown in Table 2, Slovakia's R&D expenditure and researcher density are among the lowest in the CEE region. These factors, combined with the outward migration of human capital, create vulnerabilities and constrain the country's capacity for independent scientific advancement. This context highlights why science diplomacy from global actors is particularly impactful in Slovakia, as it provides resources that might otherwise be unavailable domestically. However, these partnerships also risk reinforcing dependency and contributing to talent outflow, as many Slovak students and researchers are drawn to countries with higher R&D investments and research opportunities. According to Savov et al. (2022), factors such as inadequate financial remuneration and lack of self-development opportunities significantly hinder talent retention in Slovak companies, further exacerbating the country's challenges in maintaining a robust scientific workforce.

**Science diplomacy of the U.S. in Slovakia**. The U.S. Embassy in Slovakia has been active in promoting science and technology collaboration and investing in various programs to support these efforts. In our study, we analyzed the key initiatives and programs implemented by the U.S. Embassy to advance science diplomacy in Slovakia, including the Fulbright Program, the Benjamin Franklin Transatlantic Fellowship, and the Young Transatlantic Innovation Leaders Initiative.

One of the key findings of our study is that the U.S. Embassy in Slovakia places a strong focus on fostering science, technology, and educational collaboration as a means of building relationships between the two countries. According to respondent A, the embassy invests in programs that provide opportunities for students, researchers, and entrepreneurs to collaborate and share knowledge. For instance, the Fulbright Program offers scholarships for Slovak students and scholars to study and conduct research in the U.S., while the Benjamin Franklin Transatlantic Fellowship provides high school students with opportunities to participate in exchange programs centered on themes such as conflict resolution, social entrepreneurship, or environmental stewardship.

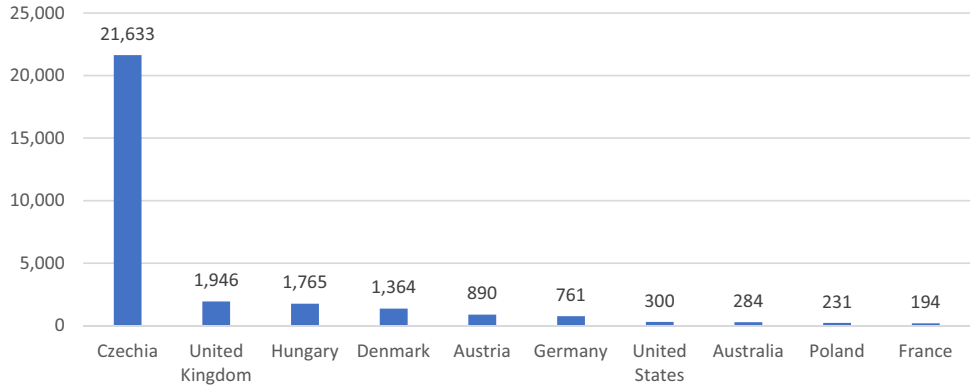


**Fig. 1** Destination countries for Slovak students studying abroad (number, 2020). UNESCO.

Another significant aspect of the U.S. Embassy's science diplomacy efforts in Slovakia is its emphasis on innovation and entrepreneurship. The embassy works to facilitate collaboration between U.S. and Slovak entrepreneurs and offers training and mentorship programs to support Slovakia's innovation ecosystem. The Young Transatlantic Innovation Leaders Initiative, for example, provides a five-month virtual entrepreneurship curriculum and a four-week fellowship experience with a U.S. company for young business and social entrepreneurs from Europe, including Slovakia.

The U.S. Embassy in Bratislava also operates a Small Grants Program (SGP) that funds projects promoting U.S.-Slovak relations and addressing issues such as democracy, rule of law, and cultural exchange. According to respondent A, the SGP prioritizes projects that foster energy security and entrepreneurship through collaboration with the U.S., including the implementation of innovative technological solutions. The program supports small-scale, high-impact projects with budgets ranging from $1000 to $25000, designed to achieve measurable results that enhance Slovakia's economic prosperity. These insights from Respondent A align with publicly available program documentation, particularly in highlighting entrepreneurship and innovation. However, the interview further emphasized the strategic dimension of these initiatives, especially their alignment with broader U.S. foreign policy objectives, which is less explicitly stated in official materials.

It is important to note that U.S. exchange programs impose a two-year home-country physical presence requirement on participants. This rule mandates that, after completing the program, participants must return to their home country for two years before becoming eligible for certain U.S. visas or permanent residency. The requirement ensures that participants apply the knowledge and skills gained during their exchange to benefit their home country. This policy applies to participants in U.S. government-funded exchange programs, home government or international organization-funded programs, and those in certain fields, such as medicine and aviation.

The U.S. approach in Slovakia closely aligns with an influence-oriented science diplomacy strategy, as defined by Flink and Schreiterer (2010). Programs such as the Fulbright Program and the Young Transatlantic Innovation Leaders Initiative foster educational exchanges that coincide with Slovakia's scientific and innovation priorities, while also reflecting broader U.S. foreign policy themes such as entrepreneurship, democratic engagement, and transatlantic cooperation. This strategy highlights the use of science as a bridge for mutual understanding and relationship-building, rather than solely as a means of promoting U.S. institutions. By leveraging its global appeal, the United States employs science diplomacy to disseminate its values and shape perceptions, consistent with the "influence" dimension of the framework.

**Science diplomacy of France in Slovakia**. In Slovakia, science diplomacy and scientific affairs are managed through cooperation and cultural action by the French Embassy in Bratislava. The cooperation and cultural action network is central to the French Foreign Ministry's soft power, outreach, and international development initiatives. In synergy with its 12 agencies and Alliance Française branches, which provide a community dimension, this network implements a global diplomatic strategy, projecting a positive and competitive image of France.

Respondent C emphasized that France primarily targets African countries and the Western Balkans as priority regions for its science diplomacy efforts. French policymakers recognize that training African youth is critical for the continent's development. While these policies aim to support Africa's progress for altruistic reasons, they also build upon France's historical ties with African nations. This includes establishing French universities and campuses in Africa, where education is predominantly offered in French, though opportunities to study in English have recently expanded.

However, Respondent C also noted that science can be exploited as a tool for technology and industry, making it vulnerable to manipulation by predatory states (e.g., China, Russia, Turkey, or Persian Gulf countries). While French embassy programs in Slovakia are publicly framed around education and EU collaboration, the interview revealed a deeper emphasis on geopolitical vigilance and the strategic use of "responsible science diplomacy" as a safeguard against potential misuse of scientific cooperation. This approach highlights the importance of anticipating risks and adopting protective measures in international research partnerships.

A key goal of the French approach to science diplomacy is to attract foreign students to France. This was confirmed by findings from interviews conducted at the French Embassy in Bratislava, which identified promoting French higher education abroad as a primary activity of French science diplomacy in Slovakia. Despite these efforts, only 194 Slovak students were studying in France as of the latest UNESCO data (Fig. 1), ranking France 10th as a destination for Slovak students abroad, with a share of just 0.6%.

The priorities of French science diplomacy include developing scientific and research cooperation, particularly through European initiatives such as the European Universities Initiative and Erasmus+ programs. These programs are considered crucial tools for fostering a shared European identity. French diplomats regard the European Universities Initiative as a hallmark achievement of French science diplomacy.

However, the position of science diplomacy within embassy priorities can be vulnerable to budget cuts. Our findings suggest that its importance is not always fully recognized or supported by all diplomats.

France's science diplomacy in Slovakia aligns with a promotion- and access-oriented strategy, as defined by Flink and Schreiterer (2010). However, its regional priorities and resource allocation suggest that Slovakia is a secondary rather than a primary focus within its global engagement. Through initiatives like Erasmus+ and the European Universities Initiative, France promotes its higher education and research infrastructure to attract Slovak students and researchers. These efforts serve both economic objectives, such as bolstering its global education sector by drawing international students, and broader goals of strengthening academic networks and collaboration. France's dedicated science attaché underscores its commitment to fostering institutional partnerships and cultural ties, ensuring that promotion and access remain central to its approach. This strategy positions France as a competitive hub for international education and a leading partner in European scientific cooperation.

**Science diplomacy of China in Slovakia**. The Chinese Embassy in Slovakia does not have a dedicated department exclusively coordinating bilateral scientific cooperation. During an interview, a representative from the embassy's political section (Respondent B) noted that science diplomacy is not frequently employed within China's foreign policy. Many scientific collaborations occur autonomously between corporations, universities, and research institutions, without direct embassy involvement. This reflects the broader phenomenon where international scientific cooperation can occur independently of diplomatic frameworks, sometimes deliberately bypassing traditional diplomatic channels (Penca, 2018). Nonetheless, intergovernmental activities, such as the China-Slovak Joint Commission of Cooperation in Science and Technology, remain in place.

China's science diplomacy initiatives have been bolstered by the China-CEEC Cooperation (16+1) platform, of which Slovakia became a member in 2012. This platform has been pivotal in fostering partnerships between China and Slovakia, particularly in academic and research spheres.

China's strategic maneuverings in the realm of science diplomacy are evidenced by initiatives such as the China-CEEC Innovation Cooperation Research Centre, which seeks to fortify innovation partnerships between China and Central and Eastern European countries, including Slovakia. The inception of this Research Centre in 2021 marks a concerted effort to establish a collaborative platform for scientific and technological advancement, with a particular emphasis on innovation.

Led by the Ministry of Science and Technology of China and backed by the People's Government of Ningbo Municipality, the Research Centre concentrates on three primary objectives. Its first objective involves the establishment of an innovation-oriented think tank coalition. This is achieved via the amalgamation of domestic and foreign universities, research institutions, and think tanks in order to conduct research on Chinese and CEE countries' science, technology, and innovation cooperation. Its second objective involves the creation of a collaborative innovation network. This network aims to gather scientific and technological resources from both China and CEE countries, facilitating the exchange and cooperation between a multitude of stakeholders, including governments, enterprises, universities, and research institutions. The Research Centre's final objective is to provide services to innovative enterprises, supporting them in their international expansion and providing advisory services for science, technology, and innovation cooperation. This facilitates the two-way transfer and transformation of innovative factors and technologies. (CCEEC, n.d.)

China supports Slovak academic endeavors through scholarships and exchange programs. The Chinese Scholarship Council offers opportunities for Slovak students and researchers to pursue studies in China. At the same time, the Slovak Academy of Sciences (SAS) collaborates with Chinese institutions on joint research projects and exchange initiatives.

A comprehensive survey conducted by the Central European Institute of Asian Studies (CEIAS) highlights the depth of Sino-Slovak academic ties, identifying 136 partnerships between Slovak and Chinese institutions. Of these, 91 are linked to Slovak public universities, and 45 involve the SAS and its affiliated research institutes.

A notable feature of China's academic involvement in Slovakia is the existence of Confucius Institutes (CI). There are presently three active CIs situated across Slovakia, which not only provide Chinese language courses within their respective host institutions but also extend their services to universities, primary schools, and secondary schools. Besides linguistic instruction, these institutes also offer courses in domains such as traditional Chinese painting, Chinese medicine, and other areas of Chinese culture. Their operations are primarily geared towards facilitating cultural exchange between the two countries and do not comprise a significant scientific exchange.

The statements provided by Respondent B reinforced the impression that China's science diplomacy in Slovakia is loosely coordinated and largely informal. This contrasts with the more structured intergovernmental and institutional platforms described in official policy documents, suggesting a divergence between declared policy ambition and on-the-ground implementation.

Concerns have emerged in several Western nations regarding China's engagement in areas like technology transfer and intellectual property theft, raising questions about the long-term repercussions of China's scientific diplomacy. However, the situation appears different in Slovakia, where evidence suggests that China's involvement has had a positive impact on international S&T collaboration. In particular, significant academic cooperation exists between Slovakia and China in the fields of engineering, technology, and natural sciences. Notable institutions such as the Slovak University of Technology and the Technical University in Košice are actively engaged in this collaboration, with partnerships also extending to Chinese technology firms like Huawei and ZTE. Huawei has notably integrated its Corporate Social Responsibility (CSR) initiative, "Seeds for the Future," within Slovakia.

Despite these positive engagements, concerns about China's science diplomacy in Slovakia have emerged, particularly regarding technology transfer and potential security risks. Some Slovak institutions, such as the Technical University in Košice and the University of Žilina, have collaborated with Chinese entities linked to military technology. CEIAS has flagged these ties as potential security risks (Šimalčík 2021). Similar concerns have been raised by the Czech think tank Sinopsis (2023), which warns that some scientific collaborations may align with China's strategic geopolitical objectives, potentially undermining democratic values. Recommendations from Sinopsis include thorough risk assessments and ensuring transparency in collaborations to safeguard national interests.

While science activities at the international level can be used to enhance the competitiveness of the national industry of the nation practising science diplomacy through the promotion of novel technologies, global standards, interoperability guidelines (Penca 2018), evidence of such outcomes in Slovakia remains

inconclusive. It is crucial to recognize that some Sino-Slovak collaborative projects, as outlined in agreements or memorandums, have not yet fully materialized. This highlights the importance of carefully evaluating and monitoring such initiatives to ensure alignment with national interests and democratic principles.

China's science diplomacy strategy in Slovakia aligns primarily with an access-oriented approach, as defined by Flink and Schreiterer (2010). The strong emphasis on accessing cutting-edge technological advancements reflects China's broader foreign policy objectives and is closely tied to its economic modernization goals. Platforms like the China-CEEC Innovation Cooperation Research Centre facilitate technological exchanges and partnerships with Slovak institutions, providing China with valuable insights and resources to advance its innovation capacity. This access-centered strategy supports China's efforts to secure a global competitive edge in strategic sectors such as AI and biotechnology, demonstrating its reliance on science diplomacy to strengthen its position in high-tech industries.

Moreover, the Chinese approach to science diplomacy may have implications for the mobility of skilled researchers from smaller countries, including Slovakia. While primarily framed around cooperation and knowledge access, China's strategic initiatives such as the Belt and Road Science, Technology and Innovation Cooperation Action Plan or now-restructured Thousand Talents Plan, have been criticized for contributing to brain drain from less research-intensive countries.

Although Slovakia has not been a major target in Chinese talent attraction policies, the increasing number of collaboration offers and institutional agreements, particularly in technical and engineering fields, could gradually influence the outward mobility of Slovak researchers. The asymmetry in research funding and institutional capacity may also increase the appeal of relocation to well-funded Chinese institutes, especially among early-career scientists.

**Comparison of science diplomacy activities of select major powers in Slovakia**. The examination of the science diplomacy strategies employed by the United States, China, and France in their engagement with Slovakia offers insights into the dynamic landscape of international scientific collaboration and its implications for small states. These three global players exhibit distinct approaches to science diplomacy, reflective of their geopolitical priorities and institutional strengths. The United States emphasizes collaboration and knowledge dissemination through extensive partnerships and exchange programs. China leverages its economic influence and regional platforms, such as the Belt and Road Initiative, to promote scientific cooperation. France prioritizes cultural ties and academic exchanges, distinguishing itself with a dedicated science attaché under the dual supervision of its embassy and the French Institute in Bratislava. By contrast, the U.S. and China incorporate science diplomacy within broader embassy functions, lacking the specialization provided by a dedicated science diplomat.

All three countries, though more intensively the United States and France, utilize non-state actors to advance their science diplomacy goals in Slovakia. The U.S. employs the Fulbright Commission, France collaborates with the French Institute, and China operates three Confucius Institutes. These actors play a crucial role in facilitating academic exchanges, research collaborations, and cultural ties.

Another common thread among the science diplomacy strategies of the three countries is the provision of scholarships for researchers and students from Slovakia. These scholarships foster student mobility and academic exchange, creating opportunities for Slovak students and scholars to gain knowledge and conduct research abroad. However, while scholarships present valuable educational opportunities, they also raise concerns about brain drain, particularly pronounced for smaller states like Slovakia.

The United States distinguishes itself with the inclusion of a two-year home-country physical presence requirement for participants of its exchange programs. This policy aims to mitigate brain drain by ensuring that the skills and knowledge acquired abroad are reinvested in the home country.

France's strategy, emphasizing the attraction of foreign students, raises concerns about brain drain, particularly given the freedom of labor movement within the EU Single Market. The fear of losing skilled individuals to more developed countries with renowned institutions and no barriers for migration is a legitimate concern. However, the fact that this concern has not materialized in the case of France's engagement with Slovakia, at least in terms of magnitude, suggests that other factors, such as strong cultural and economic ties and academic exchange programs, play a crucial role in maintaining a balance between international mobility and national retention. France's approach to fostering cultural and academic ties may also create a reciprocal relationship where Slovak students return home or maintain strong connections with Slovakia, mitigating potential brain drain.

China focuses on accessing state-of-the-art scientific and technological knowledge through partnerships and collaborations. Initiatives like the China Government Scholarships and bilateral research projects offer opportunities for scientific cooperation and migration to China. However, the cultural, geographical, and political distance between China and Slovakia acts as a natural barrier to significant human capital flight. Slovak researchers and students are less likely to permanently relocate to China than to closer or culturally similar countries.

Table 3 summarizes the findings from our analysis, detailing the objectives, actors, and effects of the science diplomacy strategies of the United States, France, and China in Slovakia.

Applying Flink and Schreiterer's heuristic reveals that the U.S., France, and China each bring distinct motivations to their science diplomacy strategies in Slovakia. The U.S. focuses on influence, France on promotion and access, and China primarily on access. This comparison underscores the diversity of science diplomacy approaches, illustrating how global powers tailor their initiatives to align with both their national interests and the unique positioning of smaller states like Slovakia. Although each country exhibits a dominant science diplomacy orientation, these dimensions are not mutually exclusive. In practice, strategic objectives often overlap, and countries may combine elements of access, promotion, and influence depending on context and institutional capacity.

Our findings suggest that Slovakia, as a small, research-dependent state, is primarily a target of access- and promotion-oriented science diplomacy efforts. This reflects its emerging role within European and global science diplomacy networks and highlights the complex interplay between international engagement and national development goals.

Despite the insights offered, this study has several limitations. The reliance on a small number of embassy interviews, conducted through varying formats (email versus in-person), introduces asymmetries in data depth and comparability. Moreover, science diplomacy strategies are dynamic and context-dependent; as such, the conclusions drawn reflect a specific temporal snapshot and may not capture recent shifts in leadership, strategic priorities, or global engagement frameworks.

**Table 3 Comparative analysis of science diplomacy of select major powers in Slovakia.**

| Country | Objectives | Actors | Effects |
|---|---|---|---|
| **U.S.** | -Exert political influence through scientific collaboration and educational exchanges | -U.S. Embassy Slovakia (Political-Economic Section)<br>-J. William Fulbright Commission for Educational Exchange | -Enhanced mutual understanding and solution-finding for societal challenges<br>-Mitigation of brain drain through return requirements |
| **France** | -Promote scientific research and higher education globally<br>- Support the status of French researchers and companies internationally | -Embassy of France in Bratislava / French Institute (Department for scientific and university cooperation) | -Strong presence in international scientific cooperation<br>-Complex impact on brain drain as strengthened academic ties bring the risk that students and scholars may remain in France for better opportunities |
| **China** | -Facilitate modernization of the economy through international scientific cooperation<br>-Build innovative strategic partnerships and promote mutually beneficial cooperation | -Embassy of China in the Slovak Republic (Political Section)<br>-China-Slovak Joint Commission of Cooperation in S&T<br>-3 Confucius Institutes | -Focus on accessing state-of-the-art scientific and technological know-how<br>-Science diplomacy mainly serves industrial development objectives rather than acting as an independent foreign policy tool |

## Conclusion

In recent years, science diplomacy has emerged as an innovative tool for promoting international cooperation and collaboration in scientific research and development. In Slovakia, efforts by major powers to advance science diplomacy demonstrate significant potential to shape the country's scientific landscape. One of Slovakia's enduring challenges is the limited funding available for scientific research and development, which constrains the ability of institutions and researchers to pursue cutting-edge innovation and attract top talent. This structural weakness is compounded by brain drain, as many of the country's most promising scientists and researchers seek career opportunities abroad.

Science diplomacy offers pathways to address these challenges by fostering international collaboration and knowledge sharing. By partnering with global stakeholders, Slovak scientists and researchers gain access to new funding sources, technical expertise, and opportunities to participate in advanced research projects. Furthermore, academic collaborations can contribute meaningfully to attracting and retaining top talent by creating prospects for international exchange and joint initiatives.

The strategies employed by the United States, China, and France in Slovakia highlight how science diplomacy can serve as a diplomatic tool to foster economic partnerships, drive technological advancement, and enhance cultural understanding. The success of these strategies depends on factors such as political alignment, cultural ties, economic incentives, and a commitment to knowledge exchange. For small states like Slovakia, a good understanding of these strategies is critical to maximizing the benefits of global engagement while mitigating vulnerabilities such as brain drain.

Recent academic reflections emphasize that science diplomacy is not a neutral or universally beneficial practice. As highlighted in the American Association for the Advancement of Science (2025) report "Science Diplomacy in an Era of Disruption", science diplomacy must increasingly confront power asymmetries, geopolitical biases, and the potential instrumentalization of science for strategic national gains rather than balanced global development. These concerns reflect recent critiques, such as those by Hussein and Awad (2024), who urge a rethinking of Western-centric models and call for a more inclusive and reflexive science diplomacy that treats all partners as equals. They highlight the persistence of unequal power relations and implicit biases that often disadvantage partners from the Global South. In this context, Slovakia, as a small state and frequent recipient of external science diplomacy efforts, must critically evaluate the benefits, structural dynamics, and potential dependencies these initiatives may reinforce.

In addition, the recently published European Framework for Science Diplomacy (European Commission, 2025) provides strategic guidance on how the EU and its member states can advance science diplomacy more effectively. The framework outlines nine key recommendations, including establishing dedicated structures, capacity building for science diplomats, and support for global challenges through inclusive and responsible scientific cooperation. For smaller EU member states such as Slovakia, engaging with this evolving EU-wide agenda offers opportunities to actively shape science diplomacy policies while strengthening national research capabilities and international visibility. This alignment may also help to balance dependency on external actors and promote more strategic, long-term cooperation models.

This study opens avenues for further research into the dynamics of science diplomacy. Future research could incorporate external variables, such as trends in international mobility, to better understand the broader context of these efforts. Another important direction would be to analyze Slovakia's own science diplomacy initiatives in partner countries. Such research may prove methodologically complex, as Slovak science diplomacy is often closely integrated with cultural diplomacy. Exploring this intersection would require attention to the role of non-state actors and informal channels.

A comparative study of how major powers conduct science diplomacy in other small states would also provide valuable insights. This could reveal whether global powers adopt uniform strategies across small states or adapt their approaches to the cultural, social, economic, and political contexts of each country. Finally, scholars could explore the role of EU partnerships in science diplomacy, investigating whether EU Member States engage differently with one another compared to their interactions with third countries in the realm of scientific cooperation.

## Data availability

The verbatim interview transcripts generated during this study are not publicly available because the participants occupy publicly identifiable diplomatic positions in Slovakia and are protected by confidentiality agreements. Sharing the data would violate the conditions of the ethical approval granted by the Ethics Committee of the Bratislava University of Economics and Business (EUBA; formerly the University of Economics in Bratislava) (Protocol No. EKEUBA/4/2024) and the informed consent provided by the interviewees. However, anonymised excerpts can be supplied by the authors upon reasonable request, after the requester has obtained written permission

from the relevant embassies of the United States, China, and France in Bratislava. All secondary documentary sources analyzed are publicly available and fully cited in the manuscript.

Received: 8 February 2025; Accepted: 8 September 2025;
Published online: 05 November 2025

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## Acknowledgements
This research received no external funding.

## Author contributions
Boris Mattoš, Michaela Grinaj, and Paskal Zhelev contributed equally to this work. Boris Mattoš supervised the study, co-designed the research framework with Paskal Zhelev, contributed to the literature review and data collection, and was involved in contextual analysis. Michaela Grinaj contributed to the literature review, data collection, and initial drafting of the manuscript. Paskal Zhelev conceived the study, co-designed the research framework with Boris Mattoš, and conducted the contextual analysis. All authors contributed equally to reviewing and revising the manuscript and approved the final version for submission. Corresponding author: Paskal Zhelev.

## Competing interests
The authors declare no competing interests.

## Ethical approval
This project involved non-interventional expert interviews with adult public officials acting in their professional capacity (April–May 2024). Under EUBA policy in force at the time of data collection, these interviews did not require prior ethics committee review because they involved no interventions or sensitive personal data and any quotations are anonymised. Before journal submission, the analysis and reporting protocol for these interviews–including confidentiality, data-protection (including GDPR) and data-storage procedures–was reviewed and approved by the Ethics Committee of EUBA (Protocol No. EKEUBA/4/2024; approved 09 December 2024). All procedures were in accordance with the 1964 Helsinki Declaration and its later amendments and the European Code of Conduct for Research Integrity.

## Informed consent
All participants provided verbal informed consent by telephone prior to participation (April–May 2024). For the in-person interview, consent was re-confirmed using a standard script and documented in contemporaneous research notes immediately before the interview; for the two email-based interviews, consent was re-confirmed at the start of the exchange via official embassy email accounts and recorded in the research log. Verbal consent was used to avoid collecting signed identifiers from high-profile public officials. In all cases, participants were informed of the study's purpose, the voluntary nature of participation and the right to withdraw at any time, confidentiality safeguards, the intended use of anonymised quotations in publications, and data-protection and storage procedures. The consent confirmation used was: *"Participation is voluntary; you may stop at any time. Your statements may be quoted in anonymised form in academic publications; we will protect confidentiality and store data securely. Do you consent to proceed?"* Each participant gave an affirmative response.

## Additional information
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