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THE ROLE OF SCIENTIFIC LEADERSHIP IN SHAPING FUTURE INNOVATORS

РОЛЬ НАУКОВОГО ЛІДЕРСТВА У ФОРМУВАННІ МАЙБУТНІХ ІННОВАТОРІВ

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Scientific leadership plays a key role in shaping future innovators by creating a favorable environment for research, creativity and interdisciplinary collaboration. Universities and research institutions are implementing mentoring programs that promote the development of critical thinking, scientific ethics and professional growth of young researchers. The study analyses models of scientific leadership, including transformational and participatory leadership, and their impact on researcher productivity, career success, and the effectiveness of mentoring programs. The results show that institutional support, quality mentoring and leadership skills of researchers contribute to the creation of an innovative environment. The practical value of the study lies in the development of recommendations for the application of forms and methods of strengthening scientific leadership in educational and research institutions. By developing interdisciplinary cooperation and international partnerships, strengthening research infrastructure, and investing in leadership development, Ukrainian universities can effectively compete in the global academic environment.

Keywords: scientific leadership, innovation, mentorship, interdisciplinary collaboration, research culture, transformational leadership, scientific ethics, career development, university.

Наукове лідерство відіграє ключову роль у створенні сприятливого організаційного середовища для досліджень, творчості та міждисциплінарної співпраці, що сприяє підготовці молодих науковців як інноваторів. Ця стаття має на меті на основі аналізу зарубіжних наукових джерел визначити сутність і роль наукового лідерства у підготовці майбутніх інноваторів, виокремити основні лідерські якості, стратегії наставництва та інституційну політику, що сприяють його розвитку. У дослідженні використано якісний підхід, що включає контент-аналіз та порівняльний аналіз програм наставництва у провідних зарубіжних університетах. Дослідження визначає трансформаційний та партисипативний стилі лідерства як найбільш ефективні моделі наукового лідерства, підкреслюючи роль менторства у розвитку критичного мислення, стійкості та продуктивності досліджень молодих вчених. Проаналізовано структуровані програми наставництва, зокрема Гарвардську ініціативу передового лідерства. Визначено роль міждисциплінарної співпраці, етичного лідерства та інституційної підтримки у створенні середовища, сприятливого для інновацій. Результати дослідження засвідчують, що наукові лідери, які беруть участь у програмах наставництва, роблять значний внесок у професійний розвиток своїх підопічних, сприяють підвищенню результативності досліджень та кар'єрному зростанню молодих дослідників. Структуровані програми наставництва надають молодим дослідникам доступ до можливостей професійних спільнот, фінансових ресурсів та навчання лідерству, що є важливими для їхнього довгострокового успіху. Підкреслено важливість сприяння інклюзивності наукового лідерства, забезпечення рівних можливостей для представлення різних груп дослідників в академічних колах і наукових дослідженнях. Практичне значення цього дослідження полягає в тому, що воно може бути використано для розроблення рекомендацій з освітньої політики, враховано при створенні стратегій розвитку для українських

закладів вищої освіти та науково-дослідних установ, які прагнуть посилити наукове лідерство. Здобуті висновки сприяють подальшому обговоренню форм і методів розвитку наукового лідерства для створення інновацій та підтримки академічної досконалості.

Ключові слова: наукове лідерство, інновації, наставництво, міждисциплінарна співпраця, дослідницька культура, трансформаційне лідерство, наукова етика, кар'єрний розвиток, університет.

Problem statement. Given the increasing importance of science in national development, global competition, and digital transformation, research on scientific leadership is essential for shaping the future of higher education and research institutions. Strengthening scientific leadership in Ukraine will contribute to the country's European integration, technological resilience, and overall academic excellence. By exploring effective leadership models, universities can enhance research productivity, foster innovation, and play a key role in global scientific advancements. Scientific leadership plays a crucial role in shaping future innovators by fostering an environment that encourages creativity, critical thinking, and research excellence within educational institutions.

Analysis of recent research and publications. A significant number of researchers are investigating key topics related to scientific leadership and its impact on innovation, with a focus on leadership styles, mentoring, institutional support and best practices. Scientific leadership extends beyond administrative roles and includes attributes such as vision, collaboration, adaptability, and ethical responsibility (Bass & Riggio 2006; Yukl, 2013) [3; 26]. Research highlights that scientific leaders are distinguished by their ability to inspire others, communicate effectively, and drive research initiatives that lead to meaningful innovations. Given the fast-paced nature of scientific discovery, leaders must adapt to new technologies, funding structures, and interdisciplinary collaborations (Kotter, 2012) [19]. Successful scientific leaders not only focus on theoretical knowledge but also drive research with real-world applications (Etzkowitz & Leydesdorff, 2000) [10]. Scientific leaders encourage innovation, challenge conventional thinking, and foster intellectual independence. Engaging faculty and students in decision-making processes promotes a culture of collaboration and shared ownership in scientific initiatives (Vroom & Jago, 2007) [25]. The Nobel laureates often exhibit transformational leadership traits, fostering creative environments where students and junior researchers feel encouraged to challenge existing theories (Shavinina, 2013) [24]. Leaders in science and academia influence students and early-career researchers by providing mentorship, facilitating access to resources and promoting a culture of inquiry.

Identification of unsolved problems. Despite numerous studies in this area, gaps remain in understanding how scientific leadership changes the organizational environment of educational institutions. The forms and methods of training young scientists as innovators require further research, especially in the period of internationalization and globalization.

Formulation of the objectives of the article (statement of the task). The main purpose of this study is to analyze the publications of foreign researchers and determine the role of scientific leadership in shaping future innovators in educational institutions. Specifically, this study seeks to:

– examine key characteristics of scientific leadership that contribute to fostering innovation in academic and research environments;

– evaluate the impact of mentorship and leadership programs on the development of students and early-career researchers;

– compare and contrast global scientific leadership programs, identifying their common and distinctive features;

– determine best practices for effective scientific leadership in promoting research excellence, interdisciplinary collaboration, and professional development.

By achieving these objectives, the study provides insights into how institutions can strengthen leadership training and mentorship programs to enhance scientific innovation.

This study employs a qualitative and comparative research approach, combining content analysis, case studies, and a literature review to assess scientific leadership programs in leading universities. The research draws from published academic sources, institutional reports, and case studies of mentoring programs to identify key leadership attributes and practices.

Presentation of the main material of the study. A fundamental characteristic of scientific leaders is their ability to articulate a clear vision for research and education. Visionary leaders inspire faculty, students, and researchers by

setting ambitious yet achievable scientific goals. Studies have shown that leaders with a well-defined vision significantly impact research productivity and institutional reputation. Effective scientific leaders set long-term research agendas that align with global scientific advancements and technological needs. Leadership in scientific domains often follows transformational and participative models rather than authoritarian styles. Transformational leadership has been widely regarded as the most effective in research environments (Bass & Riggio, 2006) [3]. Mentorship is a cornerstone of scientific leadership, playing a crucial role in shaping the next generation of innovators, researchers, and thought leaders. Effective mentorship not only transfers technical skills and knowledge but also cultivates creativity, resilience, and professional networks that are essential for long-term success in scientific fields. Scientific mentors create environments where students and early-career researchers feel free to ask questions, challenge existing paradigms, and explore new ideas. Studies indicate that intellectual autonomy in research environments leads to higher creativity and breakthrough discoveries (Eagly & Carli, 2007) [8]. The best scientific leaders empower their mentees to formulate their own hypotheses and experimental approaches, rather than simply following predefined research agendas (Deci & Ryan, 1985) [6]. Mentors who allow students to make mistakes and learn from failures help them develop confidence and resilience (Dweck, 2006) [7]. For instance, the Howard Hughes Medical Institute (HHMI) has a long-standing tradition of funding scientists with unconventional ideas, many of whom have made groundbreaking discoveries (Shamoo & Resnik, 2014) [23].

Research is inherently filled with obstacles – failed experiments, rejected papers, and funding struggles. Effective scientific leaders prepare their mentees for these realities by teaching resilience strategies and providing emotional support (Arnold, 2004) [2]. Encouraging growth mindset thinking, where failures are seen as learning opportunities rather than personal shortcomings (Dweck, 2006) [7]. Helping students develop coping mechanisms for handling rejection in academic publishing (Bozeman & Boardman, 2014) [5].

Promoting long-term goal setting rather than immediate success, so setbacks do not feel like failures but rather part of the process. A study by Freeman and Huang (2015) found that mentees who received consistent guidance and emotional support from their mentors were significantly more likely to persist in their research careers, leading to higher-impact publications [14].

This study analyzed a lot of of scientific collaborations and found that successful mentors helped mentees publish more influential research compared to those with less engaged advisors.

In particular, the research noted that mentors who actively encouraged risk-taking and interdisciplinary exploration had mentees who later became prominent in their fields.

Networking is one of the most valuable benefits of mentorship, as scientific leaders connect their mentees to key figures, funding agencies, and collaborative opportunities. Research by Kram (1985) emphasized that mentors play a critical role in integrating mentees into professional networks, ultimately influencing their career trajectories [18].

Facilitating conference participation: Encouraging students to present at major conferences, such as the American Association for the Advancement of Science (AAAS) annual meeting, significantly boosts their visibility. Scientific mentors often bridge academia and industry, opening doors to startups, corporate research labs, and government agencies (Altbach, 2004) [1]. Many grants, fellowships, and research positions are secured through mentor recommendations (Bercovitz & Feldman, 2008) [4].

The best scientific leaders encourage mentees to build global research networks, rather than confining their careers to a single institution or field. Institutions like MIT and Stanford promote cross-disciplinary collaboration, where students in AI, biotechnology, and materials science work together, leading to high-impact innovations (Kenney, 2000) [17]. Programs such as the Erasmus Mundus Joint Master Degrees (EMJMD) and the Marie Skłodowska-Curie Actions (MSCA) encourage young scientists to train under multiple mentors across different countries, increasing exposure to diverse scientific cultures (Arnold, 2004) [2]. Studies have shown that mentorship is especially critical for women and underrepresented minorities in STEM fields. A report by Eagly and Carli (2007) found that female scientists with strong mentorship support were significantly more likely to advance to leadership positions [8].

Programs like the ADVANCE initiative by the National Science Foundation (NSF) provide structured mentorship networks for under-represented scientists, increasing retention and innovation in STEM. Mentorship does not just

benefit individual mentees – it creates a cycle of leadership development, where mentored scientists go on to mentor the next generation. A study by Lunsford (2016) found that scientists who received strong mentorship early in their careers were significantly more likely to mentor others, perpetuating a culture of innovation [20].

Institutions with long-term mentorship programs, such as Harvard's Society of Fellows, consistently produce influential researchers who later establish their own mentorship networks (Shavinina, 2013) [24].

The "scientific family tree" approach, where mentors and their mentees' academic impact is traced over generations, has shown that great mentorship leads to exponential increases in scientific contributions (Freeman & Huang, 2015) [14]. The lineage of J.J. Thomson (who mentored Ernest Rutherford, who in turn mentored Niels Bohr, leading to generations of Nobel Prize-winning physicists) illustrates the compounding impact of effective scientific mentorship.

A study by Freeman and Huang (2015) showed that mentees of renowned scientific leaders tend to produce more high-impact research, demonstrating the long-term influence of mentorship [14].

Integrity and ethical responsibility are essential traits of scientific leaders, ensuring that research upholds the highest standards of credibility and transparency. Scientific misconduct, such as data falsification or unethical experimentation, can severely damage an institution's reputation and hinder future innovations (Resnik, 2007) [21]. Leaders must enforce strict ethical guidelines to prevent research fraud and plagiarism (Shamoo & Resnik, 2014) [23]. Encouraging data sharing and transparency enhances the credibility and reproducibility of research findings (Fecher & Friesike, 2014) [12]. Scientific leaders must advocate for diversity, ensuring underrepresented groups have equal opportunities in research and academia (Eagly & Carli, 2007) [8].

Institutions such as the Max Planck Society and Howard Hughes Medical Institute emphasize ethical leadership in science, setting global benchmarks for responsible research practices (Gibbons, 1994) [15].

Scientific leadership is not confined to individual excellence; rather, it thrives on collaborative networks and effective communication with multiple stakeholders, including students, faculty, funding agencies, and industry partners. Leaders must bridge knowledge gaps between fields such as artificial intelligence, biotechnology, and environmental sciences to drive innovative solutions. The ability to clearly convey complex scientific concepts to different audiences – including policymakers, investors, and the general public – is crucial (Falk-Krzesinski et al., 2011) [11]. Many scientific leaders play a role in shaping research funding and science policy at national and international levels (Altbach, 2004) [1]. For instance, the European Research Council (ERC) promotes collaborative research through grants specifically designed for interdisciplinary teams, demonstrating the impact of leadership on large-scale scientific advancement (Bercovitz & Feldman, 2008) [4].

Scientific leaders must also excel in organizational leadership to ensure that institutions provide adequate resources, funding, and infrastructure for research and innovation. Leaders must engage with government agencies, private donors, and industry to sustain long-term research projects (Bozeman & Boardman, 2014) [5]. Establishing centers of excellence, research hubs, and incubators fosters an environment conducive to innovation (Kenney, 2000) [17]. Universities with strong research cultures often empower students to take the lead in experimental projects (Arnold, 2004) [2].

A notable example is Stanford University, where scientific leadership has driven the development of Silicon Valley, showing how institutional leadership impacts broader scientific and economic landscapes (Saxenian, 1994) [22].

The characteristics of scientific leadership – vision, mentorship, ethical responsibility, effective communication, and institutional influence – are critical in shaping future innovators. As research environments become increasingly interdisciplinary and globalized, scientific leaders must adapt by fostering collaboration, advocating for ethical science, and mentoring the next generation of scientists. Institutions that invest in leadership development programs and mentorship structures are more likely to produce groundbreaking research and innovative thinkers.

Leading universities worldwide have established comprehensive mentoring programs to cultivate scientific leadership among students and professionals. These initiatives aredesigned to enhance research capabilities, leadership skills, and interdisciplinary collaboration. Below is an overview of notable programs:

1. Laidlaw Scholars Leadership and Research Programme. Established in 2014,

the Laidlaw Scholars Leadership and Research Programme operates across multiple global universities, including the University of Leeds and the University of St Andrews. This two-year undergraduate program combines independent research projects with leadership development. Scholars undertake research during summer periods and participate in leadership training, workshops, and mentoring sessions to foster ethical leadership and research excellence [13].

2. Harvard University Advanced Leadership Initiative (ALI). Harvard's ALI is designed for experienced leaders aiming to address significant social challenges. Participants, known as ALI Fellows, engage in a year-long program that includes intensive mentoring, academic coursework, and practical projects. The initiative focuses on equipping fellows with the skills necessary to lead transformative initiatives in various sectors, including science and technology [16].

3. Sloan Fellows Program. Offered at institutions like MIT, Stanford University, and London Business School, the Sloan Fellows Program targets mid-career professionals seeking advanced leadership roles. The program provides a master's degree in management and emphasizes leadership development, strategic thinking, and innovation. Participants benefit from mentorship by faculty and industry leaders, preparing them for senior positions in scientific and technological fields.

4. Schmidt Science Fellows. Launched in 2018 by Schmidt Futures in partnership with the Rhodes Trust, the Schmidt Science Fellows program offers postdoctoral fellowships aimed at developing the next generation of scientific leaders. Fellows receive mentorship from renowned scientists and are encouraged to pursue interdisciplinary research to tackle global challenges.

5. Millennium Leadership Initiative (MLI). The MLI is a leadership development program aimed at preparing individuals from underrepresented groups for university and college presidencies and chancellorships. It includes an intensive mentoring component where protégés are paired with sitting presidents or chancellors for a year, providing hands-on leadership experience and guidance.

6. Stanford Woods Institute for the Environment. The Stanford Woods Institute offers programs like the Rising Environmental Leaders Program, which provides early-career scientists with leadership training, mentorship, and networking opportunities to address environmental challenges [9].

7. NSF Research Traineeship (NRT) Program. The U.S. National Science Foundation's NRT program leverages mentoring to empower STEM graduate students to become leaders and innovators. Trainees receive technical training alongside personalized mentoring from faculty across various disciplines, promoting interdisciplinary research and leadership skills [20].

8. Mentorship Programs and Trainings at Harvard Catalyst. Harvard Catalyst emphasizes mentorship in clinical and translational research. Their programs and training opportunities are structured to support mentoring relationships across various career stages, integrating mentorship into all their offerings to foster scientific leadership. These programs exemplify the commitment of leading universities to develop scientific leadership through structured mentoring, comprehensive training, and practical experience, thereby fostering the next generation of innovators and leaders in various scientific domains. Mentoring programs at top universities share several key characteristics while also possessing unique elements that distinguish them. Figure 1 presents the common features of the mentoring programs studied.

Table 1 presents the main distinctive features of mentoring programs to cultivate scientific leadership among students and professionals.

Furthermore, the study highlights the significance of institutional support in promoting scientific leadership. Programs such as the Laidlaw Scholars Leadership and Research Programme, Sloan Fellows Program and Schmidt Science Fellows offer structured mentorship and leadership training that prepare individuals for influential roles in academia, industry, and policymaking. These programs vary in target audience, mentorship styles, and specialization, yet they share a common goal of developing future leaders equipped to address global challenges.

Scientific leadership is also closely tied to ethical integrity and responsible research practices. Leaders must uphold high academic standards, advocate for inclusivity, and promote transparency in scientific endeavors. Institutions such as the Max Planck Society and the Howard Hughes Medical Institute serve as exemplary models in maintaining ethical leadership and research excellence.

Scientific leadership is one of the important factors in ensuring the global competitiveness

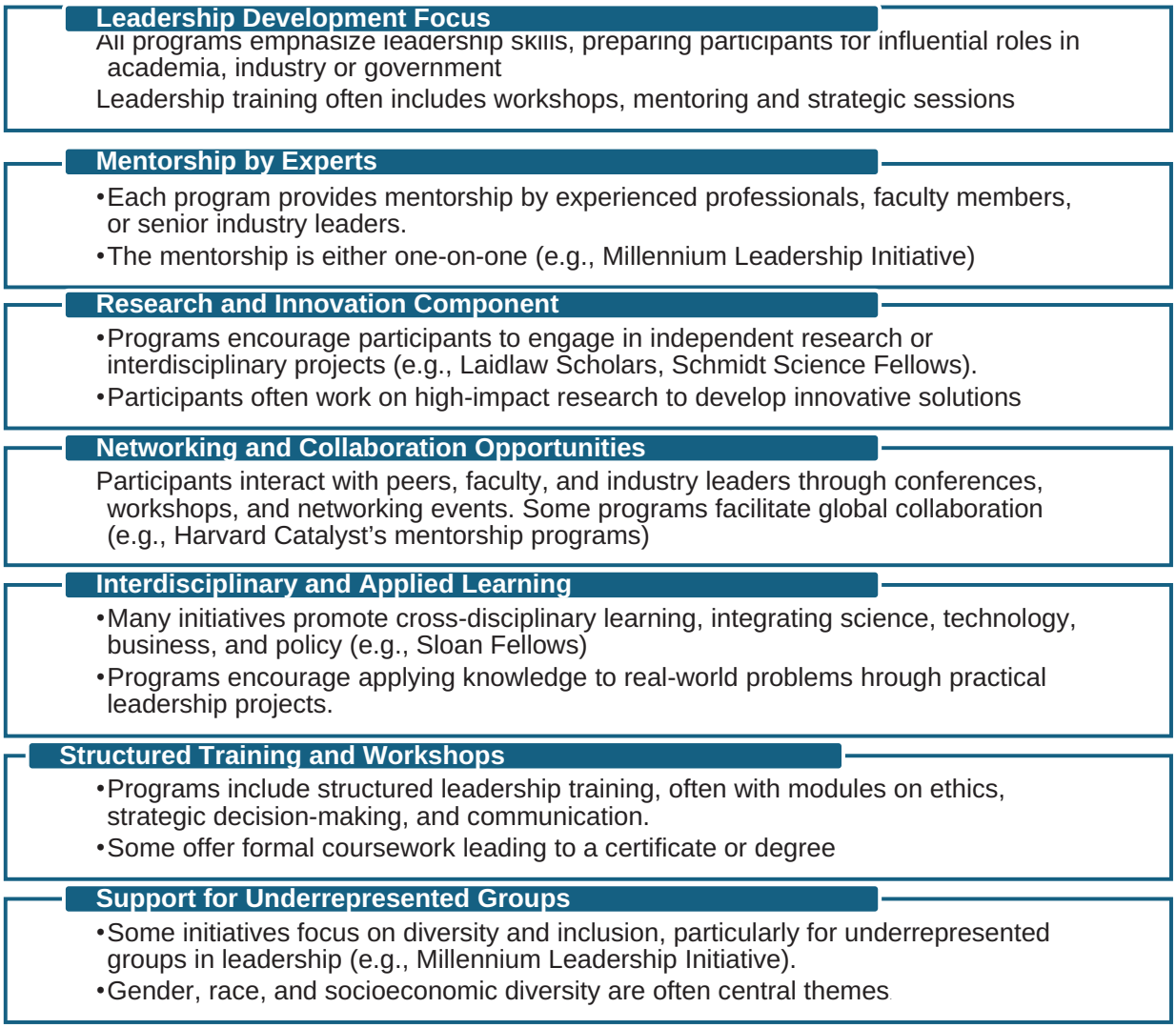

Figure 1. The common features of mentoring programs to cultivate scientific leadership among students and professionals

Sources: developed by authors based on [1–26]

of Ukrainian higher education institutions. Strengthening scientific leadership requires a combination of institutional reforms, international partnerships, and targeted support for researchers. To develop scientific leadership in Ukrainian universities, it is advisable to strengthen international partnerships and cooperation with global, in particular European, universities through joint research, mobility programs and double degree initiatives. Interdisciplinary cooperation to solve complex scientific problems is promising. To ensure transparency and accessibility of research results, it is necessary to continue the practice of publishing Ukrainian young scientists in foreign languages and sharing data in open access.

Conclusions. Scientific leadership plays a crucial role in shaping future innovators by fostering a culture of inquiry, creativity, and collaboration within educational institutions. This study highlights that effective scientific leaders possess key attributes such as vision, adaptability, mentorship, ethical responsibility, and strategic communication. These qualities not only influence research productivity but also inspire the next generation of scientists to engage in transformative and interdisciplinary work.

Mentorship emerges as a cornerstone of scientific leadership, providing young researchers with the necessary support, knowledge, and networks to succeed. The study demonstrates that institutions with strong mentoring structures, such as Harvard, Stanford, and MIT, consistently produce highly impactful scientists and thought leaders. Successful mentorship

Table 1

Distinctive features of mentoring programs to cultivate scientific leadership among students and professionals

Program	Unique Feature(s)
Laidlaw Scholars Leadership and Research Programme	Focuses on undergraduate students, offering leadership training combined with independent research.
Harvard University Advanced Leadership Initiative (ALI)	Designed for experienced leaders, providing a one-year fellowship to solve global challenges.
Sloan Fellows Program	Offers a master's degree in leadership and management, targeting mid-career professionals in science and technology.
Schmidt Science Fellows	A postdoctoral fellowship that encourages interdisciplinary research beyond the fellow's primary field of study.
Millennium Leadership Initiative (MLI)	Specifically designed for underrepresented groups, pairing them with experienced university presidents and chancellors for hands-on leadership training.
Stanford Woods Institute for the Environment	Focuses on environmental leadership, training scientists to address climate change and sustainability challenges.
NSF Research Traineeship (NRT) Program	Designed to empower STEM graduate students, integrating mentorship with cutting-edge technical training.
Harvard Catalyst Mentorship Programs	Specializes in clinical and translational research mentorship, helping scientists transition research into medical practice.

Sources: developed by authors based on [1–26]

fosters independent thinking, resilience, and professional growth, ultimately creating a cycle where mentored individuals become mentors themselves, ensuring the continuity of scientific progress.

Scientific leadership is a key driver of Ukraine's integration into the European research ecosystem. By fostering interdisciplinary collaboration, enhancing research infrastructure, and investing in leadership development, Ukrainian universities can strengthen their global standing. International partnerships, open science initiatives, and a strong research-oriented culture will enable institutions to compete effectively in the global academic landscape. As scientific environments continue to evolve, the need for adaptable and visionary leadership becomes even more critical. Future research should focus on developing assessment frameworks for evaluating scientific leadership effectiveness and exploring emerging leadership models in the digital age. Artificial intelligence, data science, and open-access publishing are reshaping how scientific leadership operates, and institutions must continuously refine their mentorship and leadership strategies to remain at the forefront of innovation.

Investing in scientific leadership is an investment in the future of research, discovery, and societal advancement. By strengthening leadership training, mentorship structures, and interdisciplinary collaborations, institutions can create an ecosystem that nurtures innovation and ensures long-term scientific impact.

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