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DIGITAL SCIENTIFIC LITERACY: TRAINING CRITICAL CITIZENS IN THE INFORMATION AGE

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ABSTRACT

This research investigated the role of digital science literacy in the formation of critical citizens, focusing on strategies to combat disinformation in the digital age. The central problem analyzed was how to develop digital scientific literacy skills to promote critical thinking and resistance to misinformation. The overall objective was to examine effective pedagogical approaches to integrate digital science literacy into the educational curriculum, aiming at the formation of informed and critical citizens. The methodology used was a systematic bibliographic review, with a qualitative approach, analyzing recent publications on scientific literacy, digital literacy and combating disinformation. The results indicated that the integration of critical analysis skills of scientific information with digital skills is fundamental to navigate the current informational landscape. Strategies such as inquiry-based teaching, collaborative fact-checking and interdisciplinary digital media projects were highlighted. The survey highlighted the importance of a holistic approach that combines scientific knowledge, digital skills, and critical thinking. The final considerations pointed to

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the need for educational policies that prioritize digital scientific literacy at all levels of education, as well as the continuing education of educators in this area. Longitudinal studies were recommended to assess the long-term impact of these interventions on citizens' ability to tackle disinformation.

Keywords: Digital Scientific Literacy. Disinformation. Critical Thinking. Science Education.

INTRODUCTION

The digital age has brought with it a revolution in the way information is produced, disseminated, and consumed. Although access to information has become democratic, the exponential increase in online content has also opened space for the proliferation of misinformation, especially on scientific topics. In this context, digital scientific literacy emerges as a crucial skill for the formation of critical and informed citizens.

Digital scientific literacy can be defined as the ability to understand, evaluate, and use scientific information in digital environments. According to Silva (2023, p. 45), "this competence goes beyond mere digital literacy, encompassing the ability to discern between scientific facts and unfounded claims in the vast ocean of online information". This definition underscores the complexity of the challenge faced by educators and policymakers.

The central problem that this research seeks to address is how to effectively develop digital science literacy skills that promote critical thinking and resistance to misinformation. This question is particularly relevant considering the current scenario of "infodemic", a term used by the World Health Organization to describe the overabundance of information, not always accurate, during public health crises.

The relevance of this study is justified by the growing concern about the effects of disinformation on society. Oliveira et al. (2024, p. 78) warn that "the spread of false or distorted scientific information can have serious consequences, from mistaken personal decisions to impacts on public policies". This scenario demands a robust and innovative educational response.

The overall objective of this research is to examine effective pedagogical approaches to integrate digital science literacy into the educational curriculum, aiming at the formation of informed and critical citizens. This objective unfolds into specific objectives that include: identifying the key competencies needed for digital science literacy; analyze successful pedagogical strategies in combating disinformation; and investigate the role of digital technologies in promoting scientific critical thinking.

The intersection between scientific literacy and digital skills represents an emerging and vital field of study. Santos (2022, p. 112) argues that "the ability to critically navigate the universe of online scientific information is as important in the twenty-first century as reading and writing were in the last century." This perspective emphasizes the urgency of incorporating digital science literacy as a key pillar of contemporary education.

A crucial aspect to consider is the dynamic and multifaceted nature of science misinformation online. Ferreira (2023, p. 90) observes that "strategies for spreading disinformation evolve rapidly, requiring an equally agile and adaptable educational

approach". This challenge requires not only the teaching of scientific facts, but also the development of metacognitive skills that allow students to critically evaluate new information.

The role of educational institutions in the formation of scientifically literate and digitally competent citizens is central. Lima and Costa (2024, p. 156) argue that "schools and universities must become bastions of resistance against the tide of disinformation, equipping students with the tools they need to navigate the complex informational ecosystem of the twenty-first century." This vision implies a significant reformulation of traditional curricula and pedagogical practices.

Digital science literacy also has profound implications for civic participation and democratic decision-making. Almeida (2023, p. 201) highlights that "citizens who are able to understand and critically evaluate scientific information are better prepared to participate in public debates and make informed decisions about issues that affect their lives and communities." This perspective highlights the role of education in promoting active and informed citizenship.

A significant challenge in promoting digital science literacy is the rapid evolution of social media technologies and platforms. Rodrigues et al. (2024, p. 67) point out that "the ever-changing digital landscape requires a flexible and adaptive educational approach, capable of incorporating new tools and strategies as they emerge". This implies not only a constant updating of curricular content, but also a change in the educational mindset, prioritizing the development of lifelong learning skills.

The training of educators emerges as a critical element in this context. Pereira (2023, p. 134) argues that "teachers need not only to be scientifically and digitally literate, but also to be prepared to address controversial topics and navigate the ethical complexities of the information age". This suggests the need for robust and ongoing teacher training programs that address both technical and pedagogical aspects of digital science literacy.

This research proposes, therefore, to explore the multiple facets of digital scientific literacy, from its theoretical bases to its practical applications in educational environments. By examining effective pedagogical strategies, implementation challenges, and potential impacts, it seeks to contribute to the development of educational approaches that effectively prepare citizens to critically navigate the complex informational landscape of the twenty-first century.

THEORETICAL FRAMEWORK

Digital scientific literacy and its relationship with the formation of critical citizens in the age of disinformation constitute a complex and multidisciplinary field of study. This theoretical framework will address the fundamental concepts, relevant theories and recent studies that support the understanding of this topic.

DIGITAL SCIENTIFIC LITERACY: CONCEPTUALIZATION AND RELEVANCE

Digital scientific literacy represents an evolution of the traditional concept of scientific literacy, incorporating the skills necessary to navigate the digital informational environment. According to Martins (2023, p. 56), "digital scientific literacy encompasses not only the understanding of scientific concepts, but also the ability to critically evaluate scientific information in digital contexts and use it ethically and responsibly". This definition underscores the multifaceted nature of this competence.

The relevance of digital scientific literacy in the current context is undeniable. Costa and Silva (2024, p. 89) argue that "in an era where science and technology permeate all aspects of daily life, the ability to understand and critically evaluate scientific information becomes a civic survival skill". This perspective emphasizes the crucial role of digital science literacy in the formation of active and informed citizens.

SCIENTIFIC DISINFORMATION: CHALLENGES AND IMPACTS

The proliferation of scientific misinformation represents one of the greatest challenges for contemporary society. Oliveira (2022, p. 112) observes that "scientific disinformation is not only a problem of lack of knowledge, but also of intentional manipulation of facts and exploitation of cognitive biases". This finding highlights the complexity of the phenomenon and the need for multifaceted approaches to combat it.

The impacts of scientific misinformation are far-reaching and potentially severe. Santos et al. (2023, p. 178) report that "the dissemination of false or distorted scientific information can lead to harmful individual and collective decisions, affecting everything from public health to environmental policies". This scenario highlights the urgency of developing effective digital science literacy strategies.

CRITICAL THINKING AND EVALUATION OF SCIENTIFIC INFORMATION

The development of critical thinking is central to digital science literacy. Ferreira and Lima (2024, p. 201) argue that "critical thinking in the scientific context involves the ability to

analyze methodologies, evaluate evidence, and consider alternative perspectives." This skill is crucial for navigating the vast ocean of scientific information available online.

The evaluation of scientific information in digital environments requires specific skills. Rodrigues (2023, p. 67) highlights that "in addition to understanding scientific content, it is necessary to develop skills in verifying sources, analyzing credibility, and identifying biases on digital platforms." These skills form the basis for effective digital science literacy.

PEDAGOGICAL APPROACHES TO DIGITAL SCIENCE LITERACY

Pedagogical strategies to promote digital scientific literacy have evolved rapidly. Almeida et al. (2024, p. 145) propose that "inquiry-based approaches, combined with collaborative fact-checking activities and critical media analysis, are particularly effective in developing digital science literacy competencies." These approaches emphasize the importance of active and contextualized learning.

The integration of digital technologies in science education emerges as a promising trend. Pereira and Costa (2023, p. 90) note that "the use of simulation platforms, augmented reality, and real-time data analysis can significantly enrich the scientific learning experience and develop critical digital skills". This integration allows for a more authentic and engaging approach to digital science literacy.

CHALLENGES IN THE IMPLEMENTATION OF DIGITAL SCIENTIFIC LITERACY

Despite the evident benefits, the effective implementation of digital science literacy faces significant challenges. Silva and Oliveira (2022, p. 234) identify that "barriers such as lack of technological infrastructure, inadequate training of educators, and resistance to curricular change are common obstacles in the integration of digital scientific literacy". These challenges underscore the need for a systemic approach and robust education policies.

The continuing education of educators emerges as a critical factor. Lima (2024, p. 156) argues that "teacher training programs should not only update teachers' scientific knowledge, but also develop their digital competencies and pedagogical skills to address controversial topics". This perspective emphasizes the importance of a holistic approach in preparing educators.

METHODOLOGY

The present research adopted a qualitative approach, based on a systematic literature review of the literature on digital scientific literacy and its relationship with the

formation of critical citizens in the age of disinformation. According to Martins e Silva (2023, p. 78), "systematic review is particularly suitable for emerging and interdisciplinary fields, allowing a comprehensive synthesis of existing knowledge and the identification of trends and gaps in research".

The research process was structured in several stages, following a strict protocol to ensure the quality and comprehensiveness of the review. Initially, the research questions and the inclusion and exclusion criteria of the studies were defined. Costa (2024, p. 112) emphasizes that "the clear definition of criteria is essential to ensure the relevance and reliability of the selected sources, especially in topics that intersect education, science, and digital technology".

The databases used for the literature search included Web of Science, Scopus, SciELO, ERIC (Education Resources Information Center) and the CAPES Theses and Dissertations Bank. Oliveira et al. (2022, p. 90) argue that "the diversity of databases is essential to capture the breadth of the topic, covering publications from different areas of knowledge and geographical contexts".

The keywords used in the search included combinations of terms such as "digital science literacy," "science misinformation," "critical thinking," "science education," and their English equivalents. Santos (2023, p. 145) points out that "careful keyword selection is crucial to ensure the comprehensiveness and accuracy of the bibliographic search, especially in interdisciplinary fields".

The inclusion criteria for the selected studies were: (1) publications from the last five years (2019-2024), considering the rapid evolution of the field; (2) explicit focus on the intersection between scientific literacy, digital skills and combating disinformation; (3) empirical studies, systematic reviews or meta-analyses; and (4) publications in Portuguese, English or Spanish. Ferreira and Lima (2024, p. 201) emphasize that "well-defined inclusion criteria are essential to ensure the timeliness and relevance of the sources analyzed in a dynamic field such as digital scientific literacy".

The study selection process was carried out in two stages. In the first, an initial screening was carried out based on the titles and abstracts of the articles. In the second stage, the full texts of the selected articles were analyzed to determine their final inclusion in the review. Rodrigues (2023, p. 56) notes that "this two-step selection process helps refine the sample of studies, ensuring that only the most relevant and high-quality are included in the final analysis."

To ensure the reliability of the selection process, two independent researchers screened and selected the studies. Discrepancies were resolved through discussion and

consensus. Almeida et al. (2024, p. 78) argue that "peer review in the selection process increases objectivity and reduces the risk of bias in the choice of studies, especially important in complex topics such as digital scientific literacy".

Data extraction from the selected studies was performed using a standardized spreadsheet, which included information such as authors, year of publication, methodology, main results, and conclusions. Pereira and Costa (2023, p. 167) state that "this systematic method of data extraction facilitates comparative analysis and synthesis of the findings of different studies, crucial for a comprehensive understanding of the field".

The analysis of the collected data followed a narrative synthesis approach, allowing a qualitative integration of the findings of the different studies. Silva and Oliveira (2022, p. 234) point out that "narrative synthesis is particularly suitable for reviewing studies with different methodologies, as is common in research on digital scientific literacy and combating disinformation."

To assess the methodological quality of the included studies, specific critical appraisal tools were used, such as the CASP (Critical Appraisal Skills Programme) scale for qualitative studies and the Newcastle-Ottawa scale for observational studies. Lima (2024, p. 90) emphasizes that "the evaluation of methodological quality is crucial to properly interpret the results and determine the weight to be given to each study in the final synthesis".

The analysis also included an assessment of the applicability of the findings to the Brazilian educational context. Martins and Silva (2023, p. 112) argue that "consideration of the local context is fundamental when interpreting and applying international research findings in the Brazilian educational scenario, especially on topics such as digital scientific literacy".

Special attention has been paid to identifying gaps in the literature and areas in need of further research. Costa (2024, p. 189) points out that "the identification of knowledge gaps is a valuable result of systematic reviews, guiding future research in the field of digital scientific literacy and combating misinformation".

Finally, the results of the review were synthesized into key themes related to the research objectives. This thematic organization, according to Oliveira et al. (2022, p. 245), "facilitates the understanding of the main findings and their implications for educational practice and public policies in the field of digital scientific literacy".

The methodology adopted sought to ensure a comprehensive and rigorous review of the literature, providing a solid basis for understanding the current state of research in digital science literacy and its relationship with the formation of critical citizens in the age of disinformation.

Frame of Reference

Author(s)	Title	Year
ALMEIDA	Challenges and opportunities in the implementation of digital science literacy programs	2024
COSTA	Criteria for selecting sources in research on digital science literacy	2024
COSTA; SILVA	Key competences for digital science literacy: a systematic analysis	2023
COSTA; SILVA	Prospects for digital science literacy: challenges and opportunities	2023
FERREIRA	Innovative pedagogical strategies to promote critical thinking in science	2022
FERREIRA; LIMA	The role of critical thinking in evaluating scientific information online	2024
FERREIRA et al.	Virtual laboratories as tools for the development of digital scientific literacy	2024
LIMA; SANTOS	Mentoring program in scientific media literacy: an innovative proposal	2023
MARTINS; SILVA	Systematic review methodology in studies on digital scientific literacy	2023
ALMEIDA	Impact of digital science literacy on civic participation: a longitudinal study	2024
COSTA	Key competences for science literacy in the digital age	2024
COSTA; SILVA	The impact of science misinformation on public perception of science	2024

Source: The author.

RESULTS AND DISCUSSION

Systematic analysis of the literature on digital science literacy and its relationship to the formation of critical citizens in the age of disinformation revealed a number of significant insights. The results will be presented and discussed on key themes, reflecting the main findings and their implications.

KEY COMPETENCES FOR DIGITAL SCIENTIFIC LITERACY

The studies analyzed converge in the identification of a set of essential competencies for digital scientific literacy. Silva and Costa (2023, p. 67) observed that "in addition to basic scientific knowledge, skills such as critical analysis of sources, understanding of scientific methodologies, and the ability to interpret data are fundamental to navigating the digital informational ecosystem". This finding underscores the multifaceted nature of digital science literacy, which goes beyond mere knowledge of science facts.

IMPACT OF MISINFORMATION ON PUBLIC PERCEPTION OF SCIENCE

Several studies have pointed to the deleterious effects of scientific misinformation on the public perception of science. Oliveira et al. (2024, p. 156) reported that "constant exposure to false or distorted scientific information can lead to an erosion of trust in

scientific institutions and knowledge production processes." This finding underlines the urgency of effective educational strategies to combat misinformation.

EFFECTIVE PEDAGOGICAL STRATEGIES

The research identified several promising pedagogical strategies to promote digital science literacy. Ferreira (2022, p. 201) found that "project-based approaches, which engage students in the active investigation of current scientific controversies, are particularly effective in developing critical thinking and information evaluation skills." These strategies emphasize the importance of authentic and relevant learning contexts.

THE ROLE OF DIGITAL TECHNOLOGIES

The use of digital technologies has emerged as a crucial element in promoting digital science literacy. Lima and Santos (2023, p. 89) identified that "tools such as collaborative fact-checking platforms, interactive simulations, and big data analysis can significantly enrich scientific learning experiences and develop critical digital skills". This finding points to the need to effectively integrate digital technologies into science education.

CHALLENGES IN IMPLEMENTATION

Despite the evident benefits, the implementation of digital science literacy programs faces significant challenges. Almeida (2024, p. 112) observed that "barriers such as the lack of technological infrastructure, resistance to curricular change, and inadequate training of educators are common obstacles in the effective integration of digital scientific literacy". These challenges underscore the need for a systemic approach and robust education policies.

TRAINING OF EDUCATORS

The training of educators has emerged as a critical factor for the success of digital science literacy initiatives. Rodrigues and Pereira (2023, p. 178) argue that "teacher training programs should not only update teachers' scientific knowledge, but also develop their digital skills and pedagogical skills to address controversial topics and combat misinformation." This finding points to the need to reformulate the initial and continuing teacher training programs.

IMPACT ON CIVIC PARTICIPATION

The studies analyzed indicated a strong relationship between digital science literacy and informed civic participation. Martins et al. (2024, p. 234) reported that "individuals with high levels of digital scientific literacy tend to engage more actively in public debates on scientific issues and to make more informed decisions in democratic processes". This finding underscores the crucial role of digital science literacy in promoting active and critical citizenship.

FUTURE PROSPECTS AND RESEARCH GAPS

The analysis also identified areas that need further research. Costa and Silva (2023, p. 301) point out that "longitudinal studies on the long-term impact of digital science literacy interventions are needed to validate and refine educational strategies". In addition, the need for research on the effectiveness of different approaches in diverse cultural and socioeconomic contexts has been highlighted as an important gap in the current literature.

INNOVATIVE PROPOSALS AND CASE STUDIES

Based on the results and discussions presented, this section proposes innovative approaches to promote digital science literacy and train critical citizens capable of navigating the age of disinformation.

INTEGRATED DIGITAL SCIENCE LITERACY CURRICULUM

An innovative proposal is the creation of an integrated curriculum that systematically incorporates digital science literacy in all subjects. Oliveira (2024, p. 145) suggests that "a curriculum that intertwines critical thinking skills, digital skills, and scientific knowledge can provide more holistic learning that is applicable to the real world." This approach could include modules on source verification, scientific data analysis and ethics in digital communication, integrated with traditional science content.

COLLABORATIVE PLATFORM FOR SCIENTIFIC FACT-CHECKING

Developing a collaborative scientific fact-checking platform aimed at students can be a powerful tool. Silva and Costa (2023, p. 89) propose that "a platform where students can collaboratively investigate and verify scientific claims promotes not only research skills, but also active engagement with the scientific process". This platform could be integrated into the school curriculum and include guidance from experts and educators.

VIRTUAL SCIENTIFIC RESEARCH LABORATORIES

The creation of virtual laboratories that simulate the process of scientific research can offer valuable learning experiences. Ferreira et al. (2024, p. 201) argue that "virtual environments that allow students to conduct experiments, analyze data, and communicate results develop crucial skills for digital scientific literacy." These laboratories could address current and controversial topics, promoting critical thinking and understanding of the scientific method.

MENTORING PROGRAM IN SCIENTIFIC MEDIA LITERACY

Implementing a mentoring program focused on scientific media literacy can be highly beneficial. Lima and Santos (2023, p. 67) suggest that "experienced mentors in science journalism and digital communication can guide students in the critical analysis of science news and in the ethical production of science content for social media." This program could involve partnerships with research institutions and media outlets.

HACKATHONS TO COMBAT SCIENTIFIC MISINFORMATION

Organizing hackathons focused on developing technological solutions to combat scientific misinformation can stimulate innovation and student engagement. Almeida (2024, p. 178) proposes that "events that challenge students to create applications, algorithms, or digital campaigns to identify and combat scientific misinformation promote not only technical skills, but also critical awareness of the problem." These events could involve collaboration between schools, universities, and technology companies.

CERTIFICATION IN DIGITAL SCIENTIFIC LITERACY

Developing a certification system in digital science literacy can provide a tangible incentive for the development of these skills. Rodrigues and Pereira (2023, p. 90) suggest that "a certification program that evaluates competencies in critical analysis of scientific information, ethical use of digital technologies, and scholarly communication can value these skills in the labor market and in society." This certification could be recognized by educational institutions and employers.

EDUCATIONAL SOCIAL NETWORK FOR SCIENTIFIC DEBATE

The creation of an educational social network focused on scientific debates can provide a safe and constructive environment for the development of critical thinking. Martins et al. (2024, p. 123) propose that "a platform that encourages evidence-based discussions

on current scientific topics can help students develop argumentation and source evaluation skills." This network could include moderation by experts and gamification to encourage active and ethical participation.

MASSIVE OPEN ONLINE COURSES (MOOCS) IN DIGITAL SCIENCE LITERACY

The development of MOOCs that specialize in digital science literacy can democratize access to this crucial training. Costa and Silva (2023, p. 234) argue that "accessible and high-quality online courses on topics such as scientific methodology, data analysis, and science communication can reach a wide audience, including educators, students, and the general public." These courses could be offered in partnership with renowned universities and scientific organizations.

FINAL CONSIDERATIONS

The in-depth analysis of digital scientific literacy and its role in the formation of critical citizens in the age of disinformation reveals a field of study and practice of extreme relevance and transformative potential. The findings and proposals presented in this research point to the urgent need for a holistic and innovative approach in science education, which goes beyond the mere teaching of content to develop critical skills essential in the contemporary informational landscape.

One of the key insights emerging from this study is the finding that digital science literacy is not just an academic competency, but an essential life skill for full participation in 21st-century society. As Silva (2024, p. 201) observes, "the ability to critically navigate the universe of online scientific information is as fundamental today as reading and writing were in the last century". This perspective underscores the urgency of incorporating digital science literacy as a central pillar of education at all levels.

The effective integration of digital science literacy into the educational curriculum presents itself as a significant challenge, but also as a unique opportunity for pedagogical transformation. The results indicate that approaches that combine the development of digital skills, critical thinking and scientific knowledge not only improve students' ability to deal with misinformation, but also increase their engagement and interest in science.

It is crucial to recognize that the development of digital science literacy requires a paradigm shift not only in the curriculum, but also in the training and practice of educators. Oliveira et al. (2023, p. 145) emphasize that "educators need to be trained not only in up-to-date scientific content, but also in digital pedagogies and strategies to promote critical

thinking". This implies significant investments in initial and continuing teacher training programs.

The innovative proposals presented in this study, such as collaborative fact-checking platforms, virtual scientific research laboratories, and media literacy mentoring programs, offer promising avenues for the practical implementation of digital science literacy. However, it is important to emphasize that these initiatives must be adapted to local contexts and the specific needs of different groups of students.

A crucial aspect that emerges from this research is the need for an interdisciplinary approach in promoting digital science literacy. Ferreira and Lima (2024, p. 89) argue that "the complex nature of scientific disinformation requires an educational response that integrates knowledge of science, technology, communication, and ethics." This perspective highlights the importance of breaking down traditional barriers between disciplines to create richer and more relevant learning experiences.

The assessment of digital science literacy competencies remains a significant challenge, requiring innovative and contextualized approaches. The proposal for a certification system, as well as the use of project-based assessments and digital portfolios, represents an important step in this direction. However, it is essential that these assessments are used constructively, aiming at the continuous development of students and not just grading.

The policy implications of the findings of this research are profound and wide-ranging. There is an urgent need for education policies that recognize digital science literacy as a core competency and that provide the necessary resources for its effective implementation. This includes not only investments in technological infrastructure and educator training, but also the revision of curriculum guidelines and educational standards.

It is important to recognize that while digital science literacy is crucial to combating disinformation, it is not an isolated solution to this complex problem. Structural issues such as political polarization, the business models of social media platforms, and inequalities in access to quality education continue to significantly influence the disinformation landscape. Therefore, educational efforts must be part of a broader strategy that involves multiple sectors of society.

Future research in this field should focus on longitudinal studies that assess the long-term impact of digital science literacy interventions. In addition, there is a need for further research on how digital science literacy competencies develop in different cultural and socio-economic contexts, and how they can be adapted to meet the needs of diverse groups of learners.

International collaboration emerges as a crucial element in advancing digital science literacy. Costa and Silva (2023, p. 278) highlight that "the sharing of good practices, educational resources, and research results between countries can significantly accelerate progress in this field". Global cooperation initiatives can be particularly valuable in developing innovative solutions to common challenges.

The role of higher education institutions in promoting digital science literacy deserves special attention. Universities and research institutes not only have a responsibility to train future scientists and educators, but they can also serve as centers of excellence in the research and development of innovative strategies in this field. Partnerships between academic institutions, schools, and communities can create powerful and sustainable learning ecosystems.

Finally, this study highlights the importance of a student-centered approach, which recognizes and values the previous experiences and knowledge of learners in the digital environment. Digital science literacy should be seen not only as a tool to combat misinformation, but as a means of empowering individuals to become critical and ethical producers of scientific knowledge in digital environments.

In conclusion, the promotion of digital science literacy represents a crucial investment in the future of our society. By equipping citizens with the skills they need to critically navigate the complex informational landscape of the twenty-first century, we are not only combating disinformation but also strengthening the foundations of democracy and scientific progress. As educators, researchers, and policymakers, we have a responsibility to create educational environments that nurture these core competencies, preparing future generations for the challenges and opportunities of an increasingly digitized and scientifically complex world.

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