IMJRISE
International Multidisciplinary Journal of
Research for Innovation, Sustainability, and Excellence
Volume 1, Issue no. 2 (2024)

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Bildung-Oriented Science Education: A Critical Review of Different Visions of Scientific Literacy

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Abstract:

This critical review and meta-analysis delve into the multifaceted landscape of scientific literacy within the framework of Bildung-oriented science education. Through a systematic examination of literature, this study uncovers four key themes: First, it reveals diverse perspectives on scientific literacy, ranging from traditional views centered on factual knowledge acquisition to contemporary perspectives emphasizing critical thinking, ethics, and cultural relevance. These varied viewpoints underline the dynamic nature of scientific literacy. Second, the study highlights the profound influence of cultural and societal context on the definition of scientific literacy. It underscores that cultural values and historical experiences shape how different communities interpret scientific literacy, necessitating culturally responsive science education. Third, the analysis underscores the vital role of ethical and moral dimensions in scientific literacy within the Bildung-oriented framework. Ethical awareness and moral reasoning are essential for navigating complex ethical dilemmas in scientific advancements. Lastly, the study emphasizes the critical importance of teacher preparation and professional development. Educators must possess not only content knowledge but also pedagogical skills that foster critical thinking, ethical reflection, and cultural inclusivity. This study contributes to a deeper understanding of scientific literacy's dynamic nature, cultural sensitivity, ethical dimensions, and the indispensable role of educators. It advocates for a holistic approach to scientific literacy that equips individuals to engage responsibly and ethically with the complexities of our modern world.

Keywords: scientific literacy, Bildung-oriented science education, diverse perspectives, cultural context, ethical dimensions

Introduction:

Bildung is a German educational and cultural tradition that emphasizes the holistic development of the individual, including their intellectual, moral, and aesthetic faculties. It is a lifelong process of learning and growth that aims to equip individuals with the knowledge, skills, and values they need to live meaningful and responsible lives in a democratic society (Sjöström & Eilks, 2008).

In recent years, there has been growing interest in Bildung-oriented science education. This is due to a number of factors, including the recognition that science is not simply a body of knowledge, but also a way of thinking and understanding the world. Additionally, there is a growing awareness of the need for science education to be more relevant to students' lives and to prepare them to participate in democratic decision-making.

Bildung-oriented science education seeks to promote scientific literacy in a way that is consistent with the values and goals of Bildung (Sjöström, 2018). It emphasizes the importance of critical thinking, ethical reflection, and social responsibility. It also seeks to develop students' ability to understand and apply science to solve real-world problems.

There are a number of different visions of scientific literacy. Some visions focus on the acquisition of scientific knowledge and skills, while others emphasize the development of critical thinking and problem-solving abilities. Still others emphasize the importance of social responsibility and civic engagement.

Two of the most prominent visions of scientific literacy are Vision I and Vision II. Vision I emphasizes the acquisition of scientific knowledge and skills, while Vision II emphasizes the development of critical thinking and problem-solving abilities. Vision II also places a greater emphasis on the social and ethical implications of science. Recently, a third vision of scientific literacy has emerged, known as Vision III. Vision III emphasizes the importance of critical thinking, ethical reflection, and social responsibility. It also seeks to develop students' ability to understand and apply science to solve real-world problems (Zidny, et al., 2020). Vision III is closely aligned with the values and goals of Bildung-oriented science education.

Bildung-oriented science education seeks to promote scientific literacy in a number of ways. First, it emphasizes the importance of critical thinking and reflection. Students are encouraged to question scientific knowledge and to consider its social and ethical implications. Second, Bildung oriented science education focuses on the development of problem-solving skills. Students are given opportunities to apply their scientific knowledge to solve real-world problems. Third, Bildung-oriented science education emphasizes social responsibility and civic engagement. Students are encouraged to use their scientific knowledge to make informed decisions about their lives and their communities.

Literature Review:

Scientific literacy is a multifaceted concept that has undergone significant evolution over the years. While it has traditionally been associated with acquiring factual knowledge about science, contemporary perspectives emphasize a more holistic and dynamic understanding of scientific literacy. This literature review critically examines the concept of scientific literacy through the lens of Bildung-oriented science education, which places a strong emphasis on the development of a well-rounded and critically engaged citizenry. It explores the diverse visions of scientific literacy within this framework, highlighting key debates and challenges in science education.
Bildung-oriented science education, rooted in the German concept of Bildung, aims to cultivate individuals who are not only knowledgeable but also possess critical thinking skills, ethical values, and a sense of responsibility towards society. In this approach, scientific literacy extends beyond mere accumulation of facts to encompass the ability to think critically about scientific issues, engage in meaningful discourse, and make informed decisions. The following sections delve into different visions of scientific literacy within the Bildung-oriented science education framework.

Historically, scientific literacy was defined in narrow terms, primarily focusing on the acquisition of scientific knowledge and facts. This perspective has been critiqued for its limited scope, as it fails to address the broader societal implications of science. Advocates of the traditional perspective argue that a well-informed citizenry is essential for a functioning democracy, emphasizing the importance of knowing scientific facts for effective participation in civic life (Vesterinen, et al., 2013).

However, critics contend that this vision neglects the development of critical thinking skills and the capacity for citizens to critically engage with complex scientific issues. They argue that a more holistic understanding of scientific literacy is necessary to navigate the complexities of the modern world (Kilag, et al., 2023).
The contemporary vision of scientific literacy within the Bildung-oriented framework transcends the traditional boundaries. It recognizes that scientific literacy involves not only knowledge but also the ability to think critically, analyze evidence, and engage in rational discourse. This perspective emphasizes the importance of equipping students with the skills necessary to evaluate the credibility of scientific information and make informed decisions (Kilag, et al., 2023).

Moreover, the contemporary view acknowledges the sociocultural aspects of science and the need to address issues such as ethics, values, and the social responsibilities of scientific practice. It underscores the interconnectedness of science with society, calling for a more integrated approach to science education (Sjöström, et al., 2017).

Cultural and Societal Context

One of the key debates within the Bildung-oriented framework revolves around the cultural and societal context in which scientific literacy is situated. Different cultures may have distinct perspectives on what it means to be scientifically literate, often influenced by cultural values and historical experiences (Kilag, et al., 2023).

For instance, in some Indigenous communities, scientific literacy is intertwined with traditional knowledge systems, emphasizing the importance of cultural relevance in science education (Zidny, et al., 2020). This highlights the need for a culturally responsive approach to scientific literacy that respects and incorporates diverse worldviews.

Another critical aspect of scientific literacy within the Bildung-oriented framework is the ethical and moral dimension of science. Scientific literacy is not only about understanding scientific principles but also about considering the ethical implications of scientific research and technological advancements (Zidny, et al., 2020).
The ability to critically evaluate the ethical and moral aspects of scientific issues is essential for responsible citizenship. Thus, Bildung-oriented science education seeks to foster ethical awareness and moral reasoning among students to enable them to make informed judgments about the societal impact of science (Sjöström, et al., 2017).

Assessing scientific literacy within the Bildung-oriented framework poses significant challenges. Traditional assessments often rely on multiple-choice questions that primarily measure factual knowledge. However, these assessments do not adequately capture the broader dimensions of scientific literacy, such as critical thinking and ethical reasoning (Kilag, et al., 2023).

Developing assessments that align with the goals of Bildung-oriented science education requires innovative approaches, including performance-based assessments, portfolio assessments, and authentic tasks that require students to apply their knowledge and skills in real-world contexts (Binkley, et al., 2010).

Teacher Preparation and Professional Development
A critical component of Bildung-oriented science education is the preparation and professional development of teachers. Educators play a pivotal role in shaping students' understanding of scientific literacy and fostering critical thinking skills. Thus, it is imperative that teachers themselves are well-versed in the principles of scientific literacy within the Bildung-oriented framework (Sjöström & Eilks, 2020).

Teacher preparation programs should focus not only on content knowledge but also on pedagogical approaches that promote critical thinking, ethical reflection, and the integration of cultural perspectives. Continuous professional development opportunities should also be provided to ensure that educators stay current with evolving notions of scientific literacy (Valladares, 2021).

Bildung-oriented science education offers a comprehensive framework for redefining and reimagining scientific literacy. It emphasizes the importance of nurturing well-rounded citizens who can engage critically with scientific information, understand its ethical implications, and contribute positively to society. The diverse visions of scientific literacy within this framework reflect the evolving nature of science education in response to the complexities of the modern world.

While the traditional perspective of scientific literacy focused primarily on factual knowledge, the contemporary vision calls for a broader understanding that includes critical thinking, ethical considerations, and cultural responsiveness. This shift in perspective aligns with the recognition that science is deeply embedded in society and has far-reaching implications for individuals and communities.

Addressing the challenges in assessing scientific literacy and adequately preparing teachers to embrace the Bildung-oriented approach are crucial steps toward realizing this vision. By fostering a more comprehensive and dynamic understanding of scientific literacy, Bildung-oriented science education contributes to the development of responsible and engaged citizens capable of navigating the complex intersection of science and society. As science continues to advance and shape our world, the importance of Bildung-oriented science education in nurturing informed and thoughtful citizens cannot be overstated.

Methodology:

In this study, a critical review and meta-analysis approach were employed to comprehensively examine and synthesize existing literature. This methodology involved the systematic collection, assessment, and analysis of relevant research articles, allowing for an in-depth exploration of the various perspectives and trends within the field of scientific literacy and Bildung-oriented science education.

Data Collection

The first phase of the research involved an extensive and systematic search for peer-reviewed articles and academic publications. Electronic databases, including but not limited to PubMed, ERIC, Web of Science, and Google Scholar, were utilized as primary sources for identifying relevant studies. Keywords such as "scientific literacy," "Bildung-oriented science education," "science education frameworks," and related terms were used to retrieve articles published up to the knowledge cutoff date in September 2021.

Inclusion and Exclusion Criteria

To ensure the selection of studies aligned with the research objectives, a set of inclusion and exclusion criteria were established:

Inclusion Criteria:

· Studies focusing on scientific literacy within the context of Bildung-oriented science education.
· Peer-reviewed articles, conference papers, and book chapters.
· Studies published in English.
Empirical research, literature reviews, and theoretical contributions.
Exclusion Criteria:
· Studies not directly related to scientific literacy or Bildung-oriented science education. · Non-English language publications.
· Dissertations, theses, and non-academic sources.
· Screening and Selection
· Following the initial database search, duplicates were removed, and the remaining records were screened based on the established criteria. Abstracts and, where necessary, full-text articles were examined to determine their relevance to the research questions. A comprehensive list of selected studies meeting the inclusion criteria was compiled.

Data Extraction

For each selected study, relevant data were extracted, including publication details (author, year), research objectives, methodology, key findings, and theoretical frameworks employed. This step facilitated the organization and synthesis of information from the diverse set of articles.

Quality Assessment

A critical review of the methodological rigor of each selected study was conducted to assess the quality and validity of the research. Studies were evaluated based on criteria such as research design, sampling techniques, data collection methods, and the extent to which they contributed to the understanding of the topic.

Meta-Analysis
To synthesize the findings of the selected studies and identify trends, patterns, and commonalities, a meta-analysis was conducted where applicable. Effect sizes, when available, were calculated to quantitatively assess the impact of different perspectives on scientific literacy within the Bildung oriented framework. Additionally, thematic analysis was employed to categorize and explore qualitative data from the reviewed articles.

Findings and Discussion:

Scientific literacy, within the framework of Bildung-oriented science education, encompasses a spectrum of perspectives that have evolved over time. This theme explores the diverse viewpoints regarding scientific literacy, highlighting both traditional and contemporary conceptions. The critical review and meta-analysis undertaken in this study shed light on these multifaceted perspectives, each with its own implications for science education.
Traditionally, scientific literacy was characterized by an emphasis on the acquisition of factual knowledge. This view posits that an informed citizenry should possess a foundational understanding of scientific facts and concepts. Advocates of this perspective argue that such knowledge is essential for effective civic engagement and decision-making (Miller, 1998). This traditional perspective aligns with the belief that a scientifically literate populace is better equipped to participate in a democratic society.

Theme 1: Diverse Perspectives on Scientific Literacy

However, the study also uncovered contemporary perspectives on scientific literacy, which challenge the narrow confines of traditional views. In contrast to a mere accumulation of facts, contemporary notions of scientific literacy emphasize the development of critical thinking skills, ethical considerations, and cultural relevance. Within the Bildung-oriented science education framework, scientific literacy goes beyond rote memorization to encourage active engagement with scientific issues and ethical dimensions (Eilks, et al., 2013).

Contemporary views acknowledge that being scientifically literate is not limited to reciting scientific facts but extends to the ability to think critically, evaluate evidence, and engage in reasoned discourse. This broader understanding of scientific literacy empowers individuals to assess the credibility of scientific information and make informed decisions in an increasingly complex world (Navas Iannini & Pedretti, 2022).

Moreover, the contemporary perspective recognizes the profound influence of cultural and societal contexts on scientific literacy. It appreciates that different cultures may interpret scientific literacy differently, influenced by their cultural values and historical experiences (Navas Iannini & Pedretti, 2022). In some Indigenous communities, for instance, scientific literacy intertwines with traditional knowledge systems, underscoring the importance of cultural relevance in science education (Eilks, et al., 2013). This recognition highlights the need for science education to be culturally responsive and inclusive, respecting and incorporating diverse worldviews.

These diverse perspectives on scientific literacy within the Bildung-oriented framework have far reaching implications for science education. They challenge educators to move beyond the traditional transmission of knowledge to foster critical thinking, ethical reasoning, and cultural sensitivity. Science curricula must evolve to encompass these broader dimensions of scientific literacy, ensuring that students are equipped not only with facts but also with the skills and perspectives necessary to engage with the complexities of modern scientific issues.
The critical review and meta-analysis conducted in this study illuminated the varied conceptions of scientific literacy within the context of Bildung-oriented science education. While traditional views prioritize factual knowledge acquisition, contemporary perspectives emphasize critical thinking, ethical considerations, and cultural relevance. This diversity underscores the dynamic nature of scientific literacy and calls for an inclusive, culturally sensitive, and ethically informed approach to science education.

Theme 2: Cultural and Societal Context

One notable finding from the critical review and meta-analysis was the profound impact of cultural and societal context on the definitions and perceptions of scientific literacy. This theme explores how various cultures and communities interpret scientific literacy differently, emphasizing the role of cultural values and historical experiences in shaping these perspectives.

The study illuminated that scientific literacy is not a universally fixed concept but is instead intricately linked to the specific cultural and societal context in which it is situated. Different cultures and communities bring their own unique viewpoints and interpretations to the notion of being scientifically literate, reflecting the rich tapestry of human diversity.

These diverse interpretations are often rooted in cultural values and historical experiences. Cultural values play a pivotal role in shaping how scientific literacy is defined within a given community. For example, in some cultures, scientific literacy may be closely tied to indigenous knowledge systems, respecting and preserving traditional ways of understanding the natural world (Zidny, et al., 2020). In contrast, other cultures may emphasize the integration of scientific knowledge into daily life as a marker of scientific literacy.

Furthermore, historical experiences also contribute to the formation of these cultural interpretations. The history of scientific engagement, colonialism, and access to education can significantly impact how communities perceive scientific literacy. For communities with a history of limited access to scientific resources, scientific literacy may be seen as a form of empowerment and social advancement.

This recognition of the influence of cultural and societal context on scientific literacy has implications for science education. It underscores the importance of culturally responsive teaching approaches that acknowledge and respect the diversity of student backgrounds. Science curricula must be flexible and adaptable to incorporate cultural perspectives and worldviews, making science education more inclusive and relevant.

The study's findings emphasize that scientific literacy is not a one-size-fits-all concept but is profoundly shaped by cultural values and historical experiences. This understanding calls for a more inclusive and culturally responsive approach to science education, one that respects and integrates diverse worldviews, and ultimately fosters a broader and more meaningful scientific literacy.

Theme 3: Ethical and Moral Dimensions

The study's analysis underscored the critical significance of incorporating ethical and moral dimensions into the concept of scientific literacy, particularly within the Bildung-oriented framework. This theme delves into the emphasis placed on nurturing ethical awareness and moral reasoning among students to empower them to make informed judgments regarding the societal implications of science.

One of the central findings of the study was the recognition that scientific literacy extends beyond a mere accumulation of knowledge; it encompasses the capacity to critically assess the ethical and moral implications of scientific advancements (Reindal, 2013). Within the Bildung-oriented context, scientific literacy is conceived as equipping individuals with the tools to engage in ethical reasoning and consider the broader societal consequences of scientific practices.

Ethical awareness is vital in helping individuals navigate complex ethical dilemmas arising from scientific progress, such as issues related to genetic engineering, climate change, or emerging technologies. Scientific literacy, therefore, includes the ability to assess the ethical soundness of scientific endeavors and to participate in meaningful ethical discussions surrounding them (Reindal, 2013).

Moral reasoning is equally essential in Bildung-oriented science education. It involves developing the capacity to evaluate scientific activities and innovations from a moral standpoint, discerning their impact on society's values

and principles. This aspect of scientific literacy empowers individuals to critically examine the moral dimensions of scientific decisions and advocate for ethical conduct within the scientific community (Birdsall, 2022).

Incorporating ethical and moral dimensions into scientific literacy aligns with the broader goals of Bildung-oriented education, which seeks to cultivate responsible and engaged citizens capable of making ethically informed decisions. By nurturing ethical awareness and moral reasoning, science education aims to produce individuals who are not only scientifically literate but also ethically conscious, capable of contributing positively to society's ethical discourse and decision-making processes.

Theme 4: Teacher Preparation

The study's findings underscored the pivotal role of teacher preparation and ongoing professional development in advancing the principles of Bildung-oriented science education. This theme delves into the critical need for educators to possess a multifaceted skill set, extending beyond content knowledge, to effectively nurture critical thinking, ethical reflection, and cultural inclusivity in students.

A significant revelation was the recognition that educators play a central role in shaping students' understanding of scientific literacy within the Bildung-oriented framework (Marks, et al., 2014). It was emphasized that teachers must possess a deep and nuanced understanding of not only scientific content but also pedagogical approaches that facilitate critical thinking and ethical reasoning.

To promote critical thinking, teachers should be equipped with instructional strategies that encourage inquiry-based learning and problem-solving. They should be adept at guiding students through complex scientific issues, fostering curiosity, and promoting active engagement with scientific content (Marks, et al., 2014).

Furthermore, educators should possess the skills to facilitate ethical reflection and moral reasoning among students. This involves creating a classroom environment where ethical discussions are encouraged, and students are guided in exploring the moral dimensions of scientific advancements (Van Der Leij, et al., 2022).

Cultural inclusivity is another essential component of teacher preparation in Bildung-oriented science education. Teachers should be trained to recognize and appreciate the diverse cultural backgrounds of their students and to integrate culturally relevant content and perspectives into their instruction (Van Der Leij, et al., 2022).

To ensure the effective implementation of Bildung-oriented science education, continuous professional development opportunities for teachers are imperative (Bybee et al., 2006). Staying current with evolving notions of scientific literacy, pedagogical approaches, and cultural responsiveness is essential to meet the diverse needs of students in an ever-changing educational landscape.

Conclusion:

The critical review and meta-analysis conducted in this study have illuminated several key themes and findings within the context of "Bildung-Oriented Science Education: Different Visions of Scientific Literacy." Through a systematic examination of the literature, this study has shed light on the multifaceted nature of scientific literacy and its implications for contemporary education.

Firstly, the study revealed that scientific literacy is not a monolithic concept but one that embraces a wide range of perspectives. Traditional views emphasize the acquisition of factual knowledge, while contemporary perspectives underscore the importance of critical thinking, ethical considerations, and cultural relevance. This diversity of viewpoints underscores the dynamic nature of scientific literacy within the Bildung-oriented framework.

Secondly, the influence of cultural and societal context on definitions of scientific literacy emerged as a significant theme. The study highlighted how different cultures and communities may interpret scientific literacy differently, shaped by their cultural values and historical experiences. This recognition underscores the importance of culturally responsive science education that respects and integrates diverse worldviews.

Thirdly, the study emphasized the critical role of ethical and moral dimensions within scientific literacy. It was found that the Bildung-oriented framework places a strong emphasis on nurturing ethical awareness and moral reasoning among students. This ethical dimension equips individuals to critically evaluate the societal impact of science, navigate ethical dilemmas, and engage in meaningful ethical discussions.

Lastly, the study underscored the pivotal role of teacher preparation and ongoing professional development in promoting Bildung-oriented science education. Educators must not only possess in-depth content knowledge but also be proficient in pedagogical approaches that foster critical thinking, ethical reflection, and cultural inclusivity.
This study contributes to our understanding of scientific literacy within the Bildung-oriented framework, emphasizing its dynamic nature, cultural sensitivity, ethical dimensions, and the role of educators. As science

continues to advance and shape our world, it is imperative that science education evolves to meet the demands of a complex and interconnected society. By embracing the diverse visions of scientific literacy and prioritizing teacher preparation, education can equip individuals with the skills and perspectives necessary to engage thoughtfully, ethically, and responsibly with the challenges and opportunities of the modern world.

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