

Sleeping Beauty Index in Scientometrics: Evaluating the Long-Term Impact of Scientific Publications and Its Applications in Research Policy

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Dear Editor,

Scientometrics has fundamentally transformed the evaluation of scientific knowledge production and dissemination. The introduction of the Science Citation Index (SCI) by Eugene Garfield in 1955 laid the foundation for modern citation-based research assessment and continues to influence contemporary scientometric analyses [1]. In the era of rapidly expanding scientific output, quantitative indicators such as citation counts, the h-index, and the journal impact factor have become central tools for evaluating research performance. However, exclusive reliance on these conventional metrics may overlook publications whose scientific influence emerges only after a prolonged period.

Over the past two decades, the use of quantitative scientometric indicators in research evaluation and science policy has increased substantially [2]. Nevertheless, traditional citation-based metrics present several important limitations. They often underestimate interdisciplinary research, emphasize quantitative performance over scientific quality, and fail to recognize pioneering studies whose influence becomes apparent only years after publication [3-5]. Although more recent platforms such as SciVal and Altmetric provide complementary perspectives on research impact, they remain primarily focused on short- to medium-term attention and are not specifically designed to identify delayed scientific recognition.

The Sleeping Beauty (SB) index was introduced by van Raan in 2004 to describe publications that receive little or no scientific attention for an extended period before experiencing a sudden and sustained increase in citations [6]. These publications typically remain dormant for at least five years before being “awakened” by new scientific developments. Empirical evidence suggests that only a small proportion of scientific papers approximately 0.1% meet the characteristics of Sleeping Beauties [6].

The Sleeping Beauty phenomenon is commonly characterized by three components: sleep duration, awakening event, and awakening intensity. Sleep duration represents the interval between publication and the onset of substantial citation activity, whereas awakening intensity reflects the magnitude of citation growth after the dormant period. Together, these characteristics provide a framework for quantifying delayed scientific recognition and identifying innovations whose importance becomes apparent only after advances in scientific knowledge or technology.

Delayed recognition may occur through several mechanisms. Scientific paradigm shifts can revive previously overlooked concepts, technological advances may enable the validation of earlier hypotheses, and new applications can reveal the broader significance of fundamental discoveries. Classic examples include Gregor Mendel’s pioneering work on genetics, which remained largely unrecognized for decades; the later technological applications of Albert Einstein’s theoretical work in satellite navigation systems; and the widespread adoption of game theory in behavioral economics long after its original development.

Unlike conventional scientometric indicators, the SB index specifically captures delayed scientific influence. One well-known example is the 1935 publication by Albert Einstein, Boris Podolsky, and Nathan Rosen on quantum entanglement, which became foundational to modern quantum information science many decades later [6]. Similarly, the landmark report by Barry Marshall and Robin Warren describing the role of *Helicobacter pylori* in peptic ulcer disease received limited initial attention but ultimately transformed clinical gastroenterology and was recognized with the 2005 Nobel Prize in Physiology or Medicine. Comparable patterns have been observed

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in several biomedical fields, including the development of positron emission tomography (PET) tracers before the widespread adoption of PET/CT imaging and early discoveries in programmed cell death that later became central to contemporary cancer therapeutics.

The SB index therefore complements traditional citation indicators by capturing the long-term trajectory of scientific influence and providing a broader understanding of how transformative discoveries gain recognition over time.

Importance of the Sleeping Beauty Index in Science Policy

The SB index has important implications for research evaluation and science policy. By identifying publications with substantial long-term influence, it can support funding agencies in recognizing projects with transformative potential that may not demonstrate immediate impact [7]. For researchers, the index provides an opportunity to identify influential work that initially appeared to have limited scientific significance but later became highly cited.

Beyond individual publications, analyses of Sleeping Beauties may inform research planning, evaluation systems, and science policy in several ways. First, patterns of delayed recognition can help identify emerging research areas and pioneering investigations that precede major scientific advances. Wang et al. reported that many Sleeping Beauties ultimately became integral to rapidly developing scientific fields [7]. Second, the SB index highlights limitations of funding systems that rely predominantly on short-term performance indicators. Consistent with this perspective, the OECD Science, Technology and Innovation Outlook 2021 emphasized the importance of supporting research with long-term innovation potential [8].

The SB index also has implications for academic evaluation. Promotion and tenure systems that depend primarily on short-term citation metrics may undervalue innovative research whose impact develops gradually. Previous studies have shown that relatively few leading universities explicitly consider delayed scientific impact in faculty evaluation frameworks [9]. Furthermore, analyses of Sleeping Beauties may provide insights into paradigm shifts within scientific disciplines, reveal biases inherent in citation-based rankings, and facilitate the development of more comprehensive scientometric models. Integrating the SB index with complementary indicators, including Altmetric data, may improve the multidimensional assessment of scientific influence [10]. Evidence also suggests that Sleeping Beauties are disproportionately represented among interdisciplinary studies, underscoring the importance of evaluation systems capable of recognizing cross-disciplinary innovation [11].

In conclusion, the SB index provides a valuable complement to conventional citation-based metrics by capturing delayed scientific recognition and the long-term impact of research. Incorporating this indicator into research evaluation frameworks may facilitate a more comprehensive assessment of scientific productivity and reduce bias against innovative studies whose

influence emerges gradually. Funding agencies, academic institutions, and policymakers should therefore consider adopting hybrid evaluation systems that combine traditional citation indicators with delayed-impact measures and alternative metrics. Such approaches may improve research assessment, support transformative science, and foster innovation across disciplinary boundaries.

Policy Recommendations

Based on current evidence, several strategies may strengthen research evaluation systems:

1. Establish dedicated databases to identify and monitor delayed-impact publications.
2. Develop funding mechanisms that explicitly support research with long-term transformative potential.
3. Incorporate delayed-impact indicators, including the SB index, into academic promotion and research evaluation frameworks.
4. Adopt hybrid assessment models that integrate quantitative citation metrics with qualitative measures of scientific influence.
5. Increase support for interdisciplinary research while considering long-term citation trajectories in research assessment.

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