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Utilization of Big Data Analytics in Strategic Decision Making in the Education Sector

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ABSTRACT

The rapid digitalization of education systems has generated an unprecedented volume, velocity, and variety of data, ranging from student academic records and learning management system logs to administrative and financial information. While this data abundance offers substantial potential for evidence-based governance, it simultaneously poses serious challenges for policymakers in extracting accurate, timely, and actionable insights to support strategic planning. Conventional decision-making approaches in education are often reactive, fragmented, and insufficiently responsive to the complexity of contemporary educational dynamics. This study aims to examine the utilization of big data analytics as an evidence-based approach to strengthen strategic decision-making in the education sector. A systematic literature review was conducted, complemented by a comparative analysis of big data analytics implementation across educational institutions in various countries, encompassing differences in technological infrastructure, institutional readiness, and policy contexts. The findings indicate that the application of big data analytics significantly enhances the accuracy of education policy formulation, optimizes the allocation of human, financial, and infrastructural resources, and strengthens predictive capabilities regarding student learning outcomes, including early identification of at-risk students. Furthermore, the integration of analytics-driven approaches facilitates more responsive and adaptive policy adjustments. These findings imply that the systematic adoption of big data analytics in education governance has the potential to serve as a foundational pillar for a more adaptive, efficient, and comprehensively data-driven transformation of education policy, while also highlighting the need for stronger data governance frameworks and analytical capacity building among educational institutions.

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1. INTRODUCTION

The massive development of information and communication technology in the last two decades has resulted in an explosion of data that is unprecedented in the history of human civilization [1–3]. Global data volumes are projected to continue to increase exponentially, creating what experts call a ”digital universe” era that is transforming the way markets and various sectors operate [4, 5]. In this context, the education sector is

not immune to the impact of this transformation, where every learning activity, academic administration, and interaction between students and educators now leaves a trail of data in enormous quantities [6]. The data comes from a variety of systems, including student information systems and online learning management platforms, as well as digital assessment instruments routinely used across educational institutions [7]. Ironically, despite the abundance of data available, the capacity of educational institutions, particularly in developing countries, to process and utilize it strategically remains very limited, resulting in the enormous potential contained in the data not being fully optimized for the benefit of continuously improving the quality of education [8, 9].

Strategic decision-making in the education sector has often relied on conventional approaches that rely on intuition, administrative experience, or aggregate data that is retrospective and inadequate to face the complexity of today's educational challenges [10, 11]. In fact, the quality of strategic decisions taken by education policy makers has a very broad impact, ranging from budget allocation, curriculum determination, recruitment of teaching staff, to the formulation of programs to increase student retention [12–14]. The need for data-driven decision making is a major motivation driving interest in analytics big data in higher education, although its application to address critical issues in this sector is still very limited [15–17]. This condition reflects a significant gap between the potential offered by technology, big data analytics and its level of adoption in actual educational governance practices, both at the institutional and national policy levels. This gap ultimately impacts institutions' weak predictability of student learning outcomes and inaccurate allocation of educational resources [8, 18].

Big data analytics emerges as a promising solution to bridge this gap by offering the ability to process, analyze, and interpret large-scale data quickly and accurately [19]. Through data collection and analysis, real-time, educational institutions can identify trends, predict outcomes, and address challenges related to student retention, academic success, and resource management more effectively and efficiently [20–22]. Furthermore, predictive modeling techniques enable institutions to make accurate projections regarding student performance, enrollment trends, and resource needs, thus supporting proactive and anticipatory strategic planning [23]. This potential is further strengthened by global trends that show very rapid growth, where the marketing data analytics in the education sector is projected to grow from US$2.703 billion in 2025 to US$11.6 billion in 2035, with a compound annual growth rate of 15.68%. This figure confirms that global investment in the utilization of big data for education continues to experience significant acceleration and cannot be ignored by policy makers [24–26].

Although the prospects are very promising, the implementation big data analytics in the education sector, there are various fundamental challenges that need to be identified and addressed systematically [27]. In Indonesia, a number of major obstacles faced include limited infrastructure, especially in areas that do not yet have fast and stable internet access, as well as a lack of human resources with specialized skills in data analysis, programming, and understanding the relevant scientific context [28–30]. In addition, the main challenge of implementing big data is the protection of student privacy and data security, where sensitive data must be protected from potential misuse, while being accompanied by strengthening technological infrastructure and adequate analytical expertise [31, 32]. These issues are not merely technical in nature, but also touch on complex and interrelated dimensions of ethics, regulation, and institutional readiness. Therefore, with a comprehensive understanding of both the opportunities and obstacles to implementing big data analytics in strategic decision making in the education sector, it has become an academic urgency that cannot be postponed [33, 34].

Based on the background and identification of the problems above, this study formulates the main question: how to utilize big data analytics can contribute optimally in supporting strategic decision-making in the education sector, and what factors determine the success of its implementation? This study aims to examine in depth the utilization patterns big data analytics in the context of strategic decision-making in educational institutions, analyzing empirically proven benefits, and identifying barriers and conditions necessary for its implementation to be sustainable and effective [35]. The novelty of this research lies in its comparative approach across contexts, by combining empirical evidence from various countries and examining its relevance to the specific conditions of Indonesia, so that the resulting findings are expected to not only contribute to the development of science, but also provide applicable policy recommendations for stakeholders in the national education sector [36].

2. RESEARCH METHODOLOGY

2.1. Type and Design of Research

This research is qualitative research with a systematic literature review approach which refers to the guide Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). This approach was chosen because the research aims to synthesize, evaluate, and integrate findings from various previously published empirical studies on the use of big data analytics in strategic decision-making in the education sector. A systematic review design is considered most appropriate given the vast amount of literature scattered across various international scientific databases, necessitating a structured, transparent, and replicable procedure to ensure the quality and representativeness of the findings. This research does not involve the collection of primary data from human subjects, but rather relies on a comprehensive analysis of secondary data in the form of journal articles, conference proceedings, and research reports that have undergone a peer-reviewed process. Overall, the flow of this research implementation consists of eight sequential stages as presented in Figure 1 below.

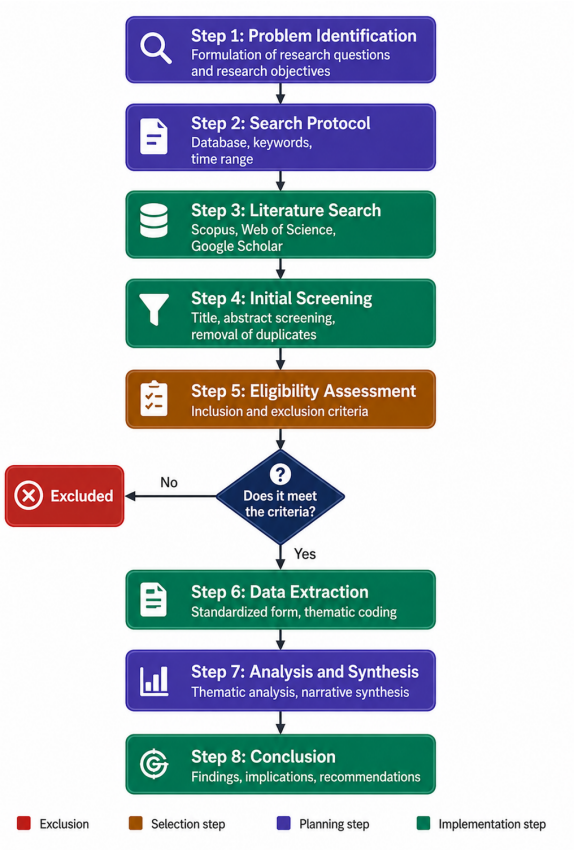

Figure 1. Research flow diagram

Figure 1 above shows that the research flow begins with problem identification and protocol development as the foundation for planning, continues with the literature search and selection process, and ends with drawing conclusions and formulating recommendations. A critical point in this flow lies at the decision node in Stage 5, where each article is rigorously assessed for eligibility before being allowed to proceed to further extraction and analysis.

2.2. Time and Place of Research

This research was conducted over six months, from January 2024 to June 2024, at the Faculty of Computer Science's research laboratory. This timeframe encompassed all stages of the research, from developing the search protocol and conducting the literature search, screening and selecting articles, data extraction, thematic analysis, and writing the final report. The timeframe was explicitly set to ensure the consistency and currency of the collected data, given that the literature in the field of information technology is developing

rapidly, and excessively broad publication timespans could potentially reduce the relevance of the findings to current conditions.

2.3. Data Sources and Search Strategy

The data in this study were sourced from scientific articles indexed in three internationally reputable databases. The databases were selected based on their broad coverage and globally recognized credibility within the academic community. Additionally, a manual search of reference lists (reference chaining) of the selected articles to ensure that no relevant studies were missed. The publication period specified was 2014 to 2024. The search strategy was designed using a combination of keywords with Boolean operators as described in Table 1 below.

Table 1. Literature Search Strategy Based on Database

Basis Data	Search String	Initial Results
Scopus	(”big data analytics” OR ”educational analytics”) AND (”strategic decision making”) AND (”education” OR ”higher education”)	847
Web of Science	(”big data” AND ”analytics”) AND (”education” OR ”learning”) AND (”decision making” OR ”policy”)	612
Google Scholar	”big data analytics” AND ”decision making” AND ”education”	423
Manual search	Reference chaining of selected articles	38
Total		**1920**

Table 1 shows that Scopus was the most productive database with 847 initial articles, followed by Web of Science with 612 articles, and Google Scholar with 423 articles. The total number before screening reached 1.920 articles, including 38 additional articles from manual searches, which were then gradually reduced through a rigorous selection process.

2.4. Inclusion and Exclusion Criteria

To ensure the quality and relevance of the analyzed literature, strict inclusion and exclusion criteria were established during the due diligence stage. These criteria are operationalized in detail in Table 2 below, which covers six dimensions of assessment.

Table 2. Article Inclusion and Exclusion Criteria

Dimensions	Inclusion Criteria	Exclusion Criteria
Topic	Discussing big data analytics in the context of education or data-driven decision making in educational institutions	Only discussing big data outside the education sector without educational relevance
Publication Type	Peer-reviewed journal articles, international conference proceedings, official institutional research reports	Editorial opinions, blogs, unofficial reports, unpublished theses
Publication Year	2014–2024	Before 2014
Language	English and Indonesian	Besides English and Indonesian
Accessibility	The full text is available openly or through institutional subscription.	Only abstract available without full text
Indexation Quality	Indexed in Scopus, Web of Science, SINTA, or DOAJ	Not indexed in any reputable database

Table 2 illustrates that the article eligibility assessment was consistently applied across all six dimensions. The application of these criteria aims to minimize selection bias and ensure that only articles with

substantive contributions to the research topic are included in the final analysis. After going through all the screening stages shown in Figure 1, 68 articles from the initial 1.920 articles were selected to meet all criteria and were used as the final corpus for analysis.

2.5. Data Collection Instruments

The primary instrument used in this study was a structured data extraction form specifically developed based on the research objectives. The form was designed to systematically and consistently capture key information from each article, including publication identity, methodological characteristics, implementation context, and type of study. Big data analytics applied the decision-making domains affected, and the key findings and challenges reported. To ensure consistency across researchers (inter-rater reliability), the form was filled out in parallel by two coders who then discussed any disagreements until a consensus was reached, with a Cohen's Kappa coefficient value of k = 0.82, which indicates a very good level of agreement.

2.6. Data Analysis Techniques

Data analysis was conducted using two complementary approaches, namely thematic analysis and narrative synthesis, as shown in Stage 7 in Figure 1. Thematic analysis was conducted following a six-phase procedure developed by Braun and Clarke, including familiarization with the data, initial coding (initial coding), grouping codes into potential themes, reviewing and refining themes, defining final themes, and writing the analysis report. The coding process was conducted using NVivo version 14, a qualitative data analysis software, which allows for more efficient management, tracking, and visualization of thematic patterns. Narrative synthesis was then used to integrate findings from multiple studies into a coherent narrative, taking into account similarities, differences, and the specific context of each study. The methodological quality of each included article was also assessed using Mixed Methods Appraisal Tool (MMAT) version 2018, to ensure that the weighting of findings in the final synthesis reflects the strength of the evidence from each study.

3. RESULTS AND DISCUSSION

3.1. Selection Results and Characteristics of Articles

The literature selection process resulted in 68 final articles meeting all inclusion criteria from a total of 1.920 initial articles found. The distribution of articles based on source database, research type, and publication year range is summarized in Table 3 below, which depicts the overall profile of the analyzed corpus.

Table 3. Characteristics of Articles Included in the Analysis (n = 68)

Category	Subcategory	Number of Articles	Percentage
Source database	Scopus	32	47.1%
	Web of Science	24	35.3%
	Google Scholar	8	11.8%
	Manual search	4	5.9%
Types of research	Quantitative	28	41.2%
	Qualitative	19	27.9%
	Literature review	15	22.1%
	Case study	6	8.8%
Year range	2014–2017	9	13.2%
	2018–2020	21	30.9%
	2021–2024	38	55.9%
Study area	North America & Europe	39	57.4%
	Asia & Southeast Asia	18	26.5%
	Africa & Middle East	11	16.2%

Table 3 shows that the majority of included articles were sourced from the Scopus database 47.1%, while articles published between 2021 and 2024 dominated the corpus, accounting for nearly 56%. These

findings indicate that research interest in the topic of big data analytics in education has experienced significant acceleration in the last three years, in line with the increasing post-pandemic digital transformation in various global educational institutions.

3.2. Domains of Big Data Analytics Utilization in Decision Making

Thematic analysis of the 68 included articles identified four main domains of big data analytics utilization in strategic decision-making in the education sector. The domain of resource allocation comes in second place, followed by curriculum planning and institutional policy. This distribution pattern is consistent with the findings of the decade review, which stated that the use of big data in decision making related to administrative functions including curriculum analysis, resource allocation, admission processes, and strategic planning are still at an immature stage and offer great potential for further exploration.

3.3. Empirical Benefits of Big Data Analytics on the Quality of Decision Making

A synthesis of the 68 included articles revealed a number of empirical benefits consistently documented across studies. Table 4 below summarizes the key benefits and the strength of the evidence supporting them.

Table 4. Empirical Benefits of Big Data Analytics in Strategic Educational Decision Making

Benefits Domain	Description of Findings	Number of Supporting Studies	Strength of Evidence
Prediction of learning outcomes	Improving the accuracy of graduation projections and early identification of students at risk of dropping out of studies	23	Strong
Curriculum planning	Adaptation of learning content based on interaction patterns and student achievements in real-time	17	Moderate–Strong
Budget allocation	Optimization of resource distribution based on needs analysis and demand prediction	14	Moderate
Student retention	Data-driven interventions that increase retention rates by 10–18%	12	Moderate
Operational efficiency	Reducing administrative costs through analytics-based process automation	9	Limited
Justice in access to education	Identify demographic gaps in learning access and outcomes	7	Limited

Table 4 shows that the highest strength of evidence is found in the domain of learning outcome prediction, supported by 23 studies with strong consistency of findings. Through predictive modeling based on historical data, educational institutions can project student outcomes, demand for study programs, and financial sustainability, thus supporting proactive strategic planning. Institutionally, data-driven decisions have been shown to contribute to improved educational outcomes and operational efficiency, with institutions leveraging big data analytics to assess program effectiveness and optimize resource allocation, which is crucial amidst the pressure of budget constraints.

3.4. Implementation Barriers: Cross-Context Findings

While its benefits have been empirically proven, the thematic analysis also identified a number of systemic barriers consistently reported across institutional and geographic contexts. These barriers are grouped into three main clusters, as shown in Figure 2 below.

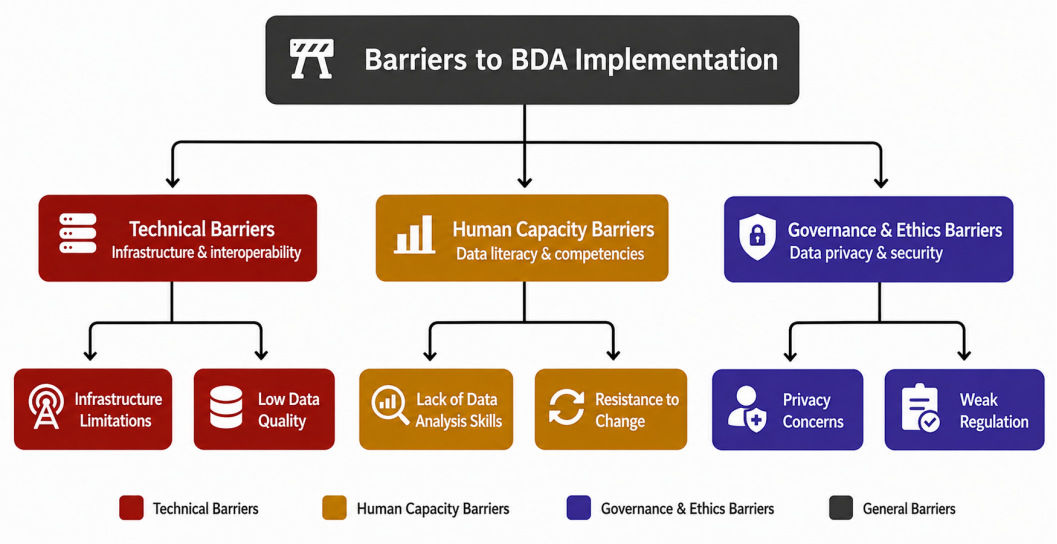

Figure 2. Barriers to BDA implementation

Figure 2 organizes the findings into three interrelated clusters. The first cluster includes technical barriers in the form of limited infrastructure and low data quality. Integration to big data analytics, the introduction of digital literacy into education poses complex ethical challenges encompassing data privacy, algorithmic fairness, transparency, and student autonomy dimensions that have not been fully addressed by existing governance. This cluster of governance obstacles is most critical because it touches on the fundamental dimension of trust between educational institutions and stakeholders.

3.5. Adoption Patterns Based on Institutional Context

A comparative analysis across the 68 included articles revealed that the adoption rate of big data analytics and their impact on the quality of decision-making varies significantly based on the institutional context. Table 5 below presents a comparison of these adoption patterns.

Table 5. Comparison of Big Data Analytics Adoption Patterns Based on Institutional Context

Institutional Context	Adoption Rate	Priority Domain	Main Supporting Factors	Major Obstacles
Major research universities (developed countries)	High	Student retention, graduation prediction	Mature infrastructure, trained human resources	Software licensing fees
Secondary college (developing countries)	Currently	Registration management	National policy support	Infrastructure & HR limitations
High school (urban)	Low–Medium	Monitoring learning achievement	Adoption of edtech platforms	Teacher data literacy is low
Secondary school (rural/3T)	Very Low	Student attendance and retention	Limited connectivity	Digital infrastructure is non-existent
Vocational education institutions	Low	Relevance of industrial curriculum	Partnership with industry	Data standard mismatch

Table 5 shows a significant adoption gap between large research universities in developed countries and educational institutions in remote areas. The EDUCAUSE 2024 study found that while most institutional leaders view analytics as a strategic priority and essential for effective decision-making, smaller institutions have far more limited access to resources and support for implementation. This finding directly reflects the

situation in Indonesia, where the capacity gap between universities in large cities and institutions in rural areas remains wide.

3.6. Discussion: Synthesis, Implications, and Further Research Agenda

The findings of this study as a whole answer the research question by showing that big data analytics has a significant and empirically documented contribution in supporting strategic decision-making in the education sector, but this contribution is conditional on the readiness of infrastructure, human resource competency, and an adequate governance framework. These results are consistent with the direction of research, which emphasized that the utilization of big data and analytics in decision-making related to administrative functions, including curriculum analysis, equity management, admissions processes, resource allocation, and strategic planning, still offer ample opportunities for exploration. However, this research goes further by systematically identifying these conditional patterns across diverse institutional contexts, a dimension that has been underexplored in previous literature, which tends to focus on a single context.

The question of why such a pattern occurs can be answered through the perspective of capacity gap theory (capacity gap theory): institutions that have a mature data ecosystem, trained human resources, and a supportive policy framework are able to convert the potential of big data analytics into real decision-making benefits, while institutions lacking one or more of these prerequisites face the risk of counterproductive implementation, including decisions distorted by low-quality data or algorithmic bias. The consequences of this gap are serious: institutions that fail to adopt big data analytics effectively risk being left behind in the quality competition, misallocating limited resources, and producing policies that are unresponsive to the real needs of students. The condition that should be realized is an ecosystem big data analytics-inclusive education, where a strong data governance framework, equitable infrastructure, and sustainable human resource capacity development are prerequisites that are addressed simultaneously rather than partially as is currently the case.

Compared with similar studies, this study complements similar studies that focused on higher education, by adding a comparative dimension across levels and geographic contexts, including the rarely explored context of developing countries like Indonesia. The practical implications of these findings for Indonesian education policymakers are the need for a phased strategy: the first priority is strengthening basic data infrastructure and student data protection regulations, followed by data literacy programs for institutional leaders, before investing in more sophisticated analytical systems. The limitations of this study lie in the literature review approach, which cannot capture the dynamics of implementation directly in the field, the dominance of English-language literature, which potentially excludes relevant local studies, and the time span of the analysis, which limits the generalizability of the findings to the rapid technological developments. Further research using a longitudinal case study approach in Indonesian educational institutions is urgently needed to produce more contextual and applicable policy recommendations.

4. CONCLUSION

This study aims to examine the utilization of big data analytics as an evidence-based approach to supporting strategic decision-making in the education sector, conducted through a systematic literature review of 68 selected articles from a total of 1.920 initial articles found in the Scopus, Web of Science, Google Scholar, and manual searches. This systematic review approach, which refers to the PRISMA guidelines, was chosen to ensure transparency and trustworthiness of the synthesis process across diverse institutional contexts, ranging from large research universities in developed countries to schools in remote areas with very limited infrastructure.

Based on the research data, it can be concluded that big data analytics has been empirically proven to provide a significant contribution to the quality of strategic decision-making in the education sector, particularly in the four main domains identified, namely student retention and learning outcomes, which occupy the highest proportion of 34% of all included studies, followed by resource allocation at 26%, curriculum planning at 23%, and institutional policies at 17%. The strongest contribution is consistently found in the domain of learning outcome prediction, supported by 23 studies with a strength of evidence assessed as strong, where predictive modeling based on historical data allows institutions to identify at-risk students early and plan interventions proactively. This finding directly answers the research question by confirming that the contribution of big data analytics is real but conditional and critically dependent on infrastructure readiness, human resource competency, and an adequate data governance framework.

The study also identified three clusters of systemic barriers consistently reported across contexts: technical barriers, including limited infrastructure and low data quality; human resource capacity barriers, including a lack of trained data analysts and resistance to change; and governance and ethical barriers, involving student privacy issues and inadequate regulation. A comparative analysis across the 68 included articles further revealed a sharp adoption gap between large research universities in developed countries, which have high adoption rates, and institutions in remote areas, which have very low adoption rates. This pattern of gaps confirms that investing in sophisticated analytics systems without first addressing the underlying capacity prerequisites can potentially lead to decisions distorted by low-quality data or algorithmic bias, thus being counterproductive to educational quality.

Based on the overall findings above, the next research agenda needs to be directed at longitudinal case studies in Indonesian educational institutions that directly examine the implementation process of big data analytics from the initiation stage to adoption maturity, taking into account local contextual factors such as data protection regulations, digital infrastructure readiness in underdeveloped, frontier, and outermost (3T) regions, and sustainable human resource capacity development models. Future Future research should also explore approaches such as federated learning and privacy-centric analytics as a promising solution to bridge the tension between the need for in-depth analytics and the protection of student data, a dimension that has not been widely studied in the Indonesian-language literature but is highly relevant to the context of national education policy.

5. DECLARATIONS

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5.2. Author Contributions

Conceptualization: AH; Methodology: SM; Software: FN; Validation: AH and MH; Formal Analysis: AH and SM; Investigation: FN; Resources: SM; Data Curation: FN; Writing – Original Draft Preparation: AH and FN; Writing – Review and Editing: AH and FN; Visualization: FN; All authors, AH, SM, FN, and MH, have read and agreed to the published version of the manuscript.

5.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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The authors received no financial support for the research, authorship, and/or publication of this article.

5.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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