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PAPER

The Impact of Blockchain Technology Effectiveness in Indonesia's Learning System

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ABSTRACT

This research investigates the integration of blockchain technology in vocational education in Indonesia, evaluating its impact on database system learning outcomes. Involving 86 Indonesian students, this study aims to assess the effectiveness of blockchain in improving students' understanding, skills, and academic performance. Using a quasi-experimental design, the findings of this study showed a significant improvement in learning outcomes, as evidenced by the analysis of pre-test and post-test scores. The measure of the effectiveness of the improvement in learning outcomes, with a substantial increase of approximately 46.50%, emphasizes the positive influence of blockchain technology on student achievement in the database systems course. The findings of this study will contribute valuable information to educational institutions, policy makers, and educators who wish to incorporate new technologies such as blockchain into their learning systems. The implication of this research is to provide recommendations in optimizing the integration of blockchain technology, which significantly affects learning outcomes in database systems. This is realized through facilitating fast and efficient access to learning materials, fostering a more interactive and engaging learning environment, and enhancing students' understanding of industry practices. The integration of blockchain into database systems learning not only improves the quality of learning but also equips students for a successful career in information technology.

KEYWORDS

blockchain technology, effectiveness, learning system, learning outcomes, database system, quasi-experimental

1 INTRODUCTION

In the realm of modern education, integrating cutting-edge technologies has become essential for enhancing learning systems and outcomes [1], [2]. One such groundbreaking technology is blockchain, initially devised as the foundational framework for cryptocurrencies but now showcasing its transformative potential across various sectors [3], [4]. This study delves into vocational education in Indonesia,

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specifically investigating the utilization of blockchain technology to assess its efficacy in enhancing database system learning outcomes.

Blockchain technology, renowned for its decentralized and secure nature, presents a unique array of advantages that can profoundly influence the educational landscape [5]. As Indonesia endeavors to establish itself as a hub for technological progress, adopting innovative solutions in education becomes imperative [6]. This research focuses on vocational education, pivotal for cultivating skilled professionals for the technology sector. By examining the integration of blockchain technology into learning systems [7], this study seeks to evaluate its effectiveness in augmenting student comprehension, skill acquisition, and overall academic performance in database systems learning.

The rapid integration of technology into global educational systems underscores the necessity for continuous innovation [8]. Blockchain, when applied in education, can furnish a transparent framework for managing academic records, foster collaborative learning environments, and streamline credential verification [9]. In the Indonesian context, where technological advancements are burgeoning [10], this research contributes to the ongoing discourse on optimizing technology-enhanced learning in vocational education.

Aligned with prior research [11], [12], blockchain technology significantly influences learning outcomes in database systems by facilitating swift and efficient access to learning materials, fostering a more interactive and engaging learning milieu, and enhancing students' grasp of industry practices. The integration of blockchain into database systems learning not only enhances learning quality but also equips students for a prosperous career in information technology.

In line with the research [13], [14], [15], the benefits of blockchain technology in enhancing the learning outcomes of database systems can be linked to pertinent material in several ways. Firstly, the concept of transparency in data storage and management, taught in database system materials, is reinforced by blockchain's decentralized and transparent nature. Secondly, learning about data security in database systems is enriched by blockchain's security features such as encryption and decentralization. Thirdly, blockchain integration broadens students' understanding of its application in industries like finance and healthcare. By connecting database system material with the advantages of blockchain technology, students can amalgamate theory with practical applications, fortify their understanding of key concepts, and be prepared to confront real-world work challenges.

This research not only directly impacts student learning outcomes but also holds broader implications for educational institutions, policymakers, and educators. By comprehensively analyzing the integration process, exploring potential challenges, and attending to stakeholders' perceptions, this research offers invaluable insights for the development of a dynamic and future-oriented education system in Indonesia. Through a mixed methodology approach that amalgamates quantitative and qualitative data, it is envisaged that this research can furnish a deeper understanding of blockchain technology's effectiveness in enhancing database system learning outcomes in the context of vocational education in Indonesia.

2 METHODOLOGY

The theoretical foundation of this research is the Technology Acceptance Model (TAM), which was first developed to investigate how new technology adoption occurs [16], [17]. The Theory of Reasoned Action (TRA), which focuses on how individuals

assess the value and benefits of blockchain technology, forms the basis of this model [18], [19]. Usability-related aspects are used to measure the extent to which the new technology can improve student performance, while ease-of-use aspects are used to evaluate how accessible the technology is. In this study, TAM was used to evaluate the acceptance and use of blockchain technology among vocational education students in Indonesia. Using TAM, this study intends to identify the extent to which students consider that the use of blockchain technology brings benefits and convenience in the context of informatics engineering learning. Thus, TAM provides a strong conceptual framework for understanding how students' perceptions and attitudes towards blockchain technology affect their level of acceptance and utilization in the context of vocational education.

This study employed a quasi-experimental design [20], [21] and used a one-group pretest-posttest design for data analysis presented [22] in Figure 1. A sequential two-stage design was implemented to collect comprehensive information. In the first stage, data was collected through an exploratory technique test using blockchain technology. Furthermore, in the second stage, questionnaire data was analyzed using a Likert response scale (five points) given to the research sample. This analysis aims to assess students' perceptions or responses to the ease of use, usability, and accessibility aspects of using blockchain technology after the intervention.

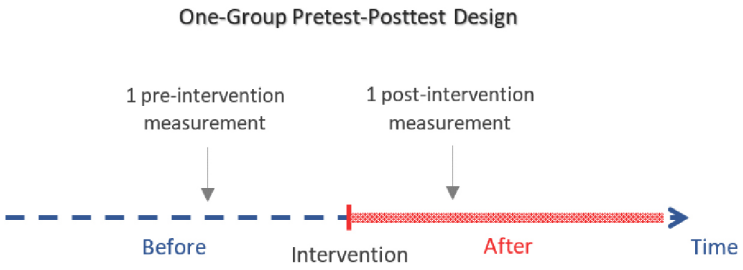

Fig. 1. Quasi-experimental design

Figure 1, In this study, a quasi-experimental design with pretest and posttest procedures was used. This design was chosen because this study did not involve a comparison group, so only one group of participants was identified. The study was conducted at Universitas Negeri Yogyakarta (UNY) in the vocational education department, Indonesia. Participants consisted of 86 students majoring in Informatics Engineering Education (PTI) and Informatics Engineering (IT), who showed uniformity in age group (19–23 years old), Indonesian language proficiency, education level, length of study, and database system experience with related technologies. The pretest procedure was conducted before the intervention using blockchain technology, while the posttest was conducted after the intervention. Data from the pretest and posttest were then analyzed to evaluate changes in students' understanding, skills, and academic performance after the use of blockchain technology in database system learning.

2.1 Collection technique and research sampling

This research employs data collection techniques known as convenience testing, also referred to as purposive, specific, critical, or abstract testing. This technique is a representation of a nonprobability testing strategy that focuses on testing methods where sample members are selected based on availability and convenience to the

researcher. Although this kind of testing technique may be less appealing than other methods of examination, its success lies in its ability to answer the research question by considering the specific attributes of the population on which the research focuses. In this context, this study uses convenience sampling because this sampling technique has the advantages of efficiency and affordability. This method is very efficient in data collection because it selects respondents who are easily accessible, so the process is fast, and the cost is relatively low. Another advantage is the easy sampling technique, which is the only accessible method for database systems courses. Its ease of implementation, without requiring complex planning, allows researchers to collect data without having to compile sample lists or make complex arrangements. The speed of data collection becomes relevant in time-constrained situations, such as urgent research that requires quick results. This method is also suitable for preliminary research that provides an initial overview of the topic without requiring significant time and resources. The practicality of convenience sampling arises in situations where selecting a random or detailed sample from a larger population is not possible or requires excessive effort. Despite these advantages, keep in mind that results from convenience sampling may not fully reflect the population accurately due to possible biases, so the results need to be interpreted with caution and confirmed by research with more representative sampling methods where possible.

Data in this study were gathered through surveys, analysis of learning outcomes, and questionnaires to obtain quantitative information [23]. To assess students' performance in lectures, data on the understanding of the database system were collected using an analysis that included 60 multiple-choice questions. Additionally, questionnaires were employed to gather responses from vocational education students regarding the learning system involving blockchain technology. The researcher evaluated learning activities based on the outcomes test, which also included an assessment of the challenges in understanding blockchain technology. This treatment was administered to a pre-test sample of 86 informatics engineering (IT) students after the test, ensuring the reliability of the utilization of blockchain technology. In its implementation, this study used a questionnaire with a Likert rating scale to collect data on student responses to blockchain technology [24]. The focus of this study was on the aspects of ease of use, usability, and accessibility of blockchain technology. This questionnaire consists of 16 items which are divided into three categories, namely usability, ease of use, and accessibility. Research validators are lecturers from Universitas Negeri Yogyakarta who have competence in accordance with the research field and provide comments on the questionnaire used. Comments and suggestions from validators were taken into consideration, with some question elements removed and added according to research needs. The validity results indicate that the r-count value is 0.499, surpassing the r-table value of 0.322 for 86 informatics engineering (IT) students. Based on the instrument validity criteria, where r-count ≥ r-table, the entire research questionnaire is deemed valid (0.499 > 0.322). The reliability of the questionnaire was assessed using Cronbach's alpha on a trial sample of 86 students. The reliability outcomes revealed alpha values ranging from 0.84 to 0.89 for the domains and 0.91 for the overall scale, affirming the survey's reliability.

2.2 Application of blockchain technology intervention

The integration of blockchain technology into database system courses aims to improve the efficiency of the learning process and ensure data security.

The decentralized and transparent nature of blockchain provides robust data security, safeguarding the integrity and authenticity of information within database systems and minimizing the potential for data theft or unauthorized alterations [25], [26]. Moreover, blockchain introduces transparency and auditability by meticulously recording each transaction or data modification, allowing lecturers and students to effortlessly trace the chronological evolution of changes and maintain transparency throughout the learning process [27], [28]. The incorporation of blockchain technology further facilitates a practical comprehension of distributed databases, enlightening students on how data is distributed and managed across the blockchain network [13]. The utilization of smart contracts in administrative functions streamlines processes such as grading, assignments, and other administrative tasks, thereby reducing the likelihood of human error [12]. Additionally, this technology serves as a platform for fostering innovation, providing students with hands-on experience, and preparing them for the dynamic challenges of the rapidly evolving industry [29]. Collaborative projects leverage blockchain as a foundational platform, enabling students to collaboratively construct and manage blockchains that emulate distributed databases. This not only refines their collaborative and technical skills but also nurtures a collaborative learning environment [30]. Monitoring student progress is significantly enhanced with the implementation of blockchain, enabling lecturers to precisely track individual advancements through transparent and verified records [31]. In summary, the application of blockchain technology in the database systems course yields substantial advantages, enhancing security, fostering transparency, and instilling the latest technological concepts. This approach cultivates an innovative learning environment aligned with the evolving needs of the industry. The statistical analysis for this study utilized the Statistical Package for the Social Sciences (SPSS Version 21), incorporating mean values, standard deviations, frequencies, and percentages to address the three research questions [32]. The paired sample t-test was employed to ascertain the significance of the difference between pre-test and post-test outcomes for the database systems course [33].

3 RESULT AND DISCUSSION

Using the research results from the pre-test and post-test evaluation of students in the database system course exam, researchers investigated the impact of the effective use of blockchain technology in improving learning outcomes in the database system course for Informatics Engineering (IT) students. The results of the data analysis presented in Table 1 show the students' total scores before and after the exam, as well as the results of the paired sample t-test which showed a significant difference between the students' pre-test and post-test scores. With an effect size of 43.81% on the pre-test, the post-test results (46.52%) were seen to be superior compared to the pre-test results.

Table 1. Pre-test result

Learning Outcomes of Database System Courses	Mean	Std. Dev	t-Test	Size-Effect	Significant Value
Pre-test results	33.84	12.88	14.36	43.81%	$\alpha \leq 0.05$
Post-test results	42.40	24.21			

This study aims to assess the impact of blockchain technology on the learning outcomes of database systems courses among Informatics Engineering Education (PTI) students. The investigation involved identifying the pre-test and post-test scores for the database systems lesson. Table 2 presents the students' scores comprehensively, highlighting the differences between the pre-test and post-test results. The results of the paired samples t-test showed a statistically significant difference between the mean pre-test and post-test scores of the students. The effectiveness measure of the database systems learning outcome was 46.52%, signifying a substantial increase in post-test scores compared to pre-test scores.

Table 2. Post-test result

Learning Outcomes of Database System Courses	Mean	Std. Dev	t-Test	Size-Effect	Significant Value
Pre-test results	35.15	13.05	17.04	46.52%	$\alpha \leq 0.05$
Post-test results	47.94	19.59			

In addition, from the evaluation of students' responses to 16 questions consisting of three aspects (usability aspect, ease of use aspect, and accessibility aspect) in the post-test after the adoption of blockchain technology, the researcher conducted a quantitative assessment of the attitude of Informatics Engineering Education (PTI) students regarding blockchain technology. The results used descriptive statistical analysis of both the average and standard deviation which aims to obtain student responses regarding the field of blockchain technology.

The results of data analysis on Information Technology Education (PTI) students, show that the aspect of ease of using blockchain technology is ranked the highest, as shown in the results of data analysis presented in Table 3 based on the average (4.56 ± 0.23). The second most significant aspect is the usefulness of blockchain technology (4.28 ± 0.26). Nonetheless, the average score of the accessibility aspect (4.17 ± 0.39) was considered the lowest. Based on this research, students' responses or perceptions have an average score of (4.35 ± 0.29).

Table 3. Informatics engineering education (PTI) student response results

Criteria	Mean	Std. Dev	Category
Responses in the ease domain	4.56	0.23	High
Responses in the usefulness domain	4.28	0.26	High
Responses in the access domain	4.17	0.39	High
Total	4.35	0.29	High

The results of data analysis on Informatics Engineering students, as presented in Table 4, show that the ease-of-use aspect of blockchain technology is ranked the highest (4.62 ± 0.39), while the usability aspect of blockchain technology is ranked second (4.44 ± 0.28) based on the average value of the database system course learning outcomes. On the other hand, the average value of the accessibility aspect of blockchain technology, namely (4.20 ± 0.29), is considered the lowest. With these findings, the student response to the use of blockchain technology has an average value of (4.40 ± 0.32).

Table 4. Informatics engineering (TI) student response results

Criteria	Mean	Std. Dev	Category
Responses in the ease domain	4.62	0.39	High
Responses in the usefulness domain	4.44	0.28	High
Responses in the access domain	4.20	0.29	High
Total	4.40	0.32	High

The results of descriptive statistical analysis describing student responses to aspects of ease of use, usability aspects, and data accessibility aspects are presented in Tables 5 and 6. Table 5 illustrates that student majoring in Informatics Engineering Education (PTI) give a good assessment of blockchain technology, which indicates a good assessment in terms of usability, ease of use, and accessibility.

Table 5. Informatics engineering education student (PTI) responses

Aspects	Criteria	Mean	Std. Dev	Category	Assessment Sequence
Usability Assessment Criteria	The extent to which blockchain technology aligns with the learning objectives that have been set in the vocational education database system course.	4.88	0.36	High	1
	How effectively blockchain contributes to improving the overall learning experience, engagement, and comprehension of database system concepts among students.	4.44	0.50	High	
	The degree to which blockchain technology provides practical insights and applications relevant to real-world scenarios and industry practices within the field of database systems.	4.43	0.50	High	
	How well blockchain technology aids in enhancing students' conceptual understanding of database system principles, structures, and functionalities.	4.42	0.89	High	
	The adaptability and compatibility of Blockchain technology with current and future technological trends in the domain of database systems.	4.29	0.46	High	
	The extent to which blockchain technology fosters collaborative learning environments, encouraging students to work together in understanding and applying database system concepts.	4.15	0.36	High	
	The accessibility and user-friendliness of Blockchain tools and platforms, ensuring that students can easily navigate and utilize them to enhance their learning experiences.	4.13	0.86	High	
	The anticipated long-term impact of incorporating blockchain technology on students' career development within the database system field, including potential job opportunities and skill enhancement.	3.97	0.78	Mid	
Ease of Use Criteria Assessment	The simplicity of blockchain technology for students in vocational education, in ensuring ease of use.	4.73	0.46	High	2
	Effectiveness of blockchain technology in improving learning outcomes.	4.57	0.50	High	
	Blockchain technology helps in overcoming challenges and maximizing student understanding.	4.43	0.48	High	
Access Assessment Criteria	How easy it is for students to access blockchain technology tools and platforms	4.72	0.46	High	3
	Is the blockchain technology integrated with the learning management system	4.43	0.48	High	
	How secure is the blockchain technology	4.29	0.43	High	
	Whether blockchain technology can be accessed and used anytime and anywhere	3.74	0.72	Mid	

Furthermore, the data analysis results for most students majoring in informatics engineering (IT) reveal positive evaluations of blockchain technology in the learning process. Table 6 demonstrates that students gave a good assessment across the usability, ease of use, and accessibility aspects.

Table 6. Informatics engineering student (TI) responses

Aspects	Criteria	Mean	Std. Dev	Category	Assessment Sequence
Usability Assessment Criteria	The extent to which blockchain technology aligns with the learning objectives that have been set in the vocational education database system course.	4.83	0.36	High	1
	How effectively blockchain contributes to improving the overall learning experience, engagement, and comprehension of database system concepts among students.	4.61	0.48	High	
	The degree to which blockchain technology provides practical insights and applications relevant to real-world scenarios and industry practices within the field of database systems.	4.48	0.49	High	
	How well blockchain technology aids in enhancing students' conceptual understanding of database system principles, structures, and functionalities.	4.46	0.77	High	
	The adaptability and compatibility of blockchain technology with current and future technological trends in the domain of database systems.	4.43	0.50	High	
	The extent to which blockchain technology fosters collaborative learning environments, encouraging students to work together in understanding and applying database system concepts.	4.31	0.78	High	
	The accessibility and user-friendliness of Blockchain tools and platforms, ensuring that students can easily navigate and utilize them to enhance their learning experiences.	4.21	0.76	High	
	The anticipated long-term impact of incorporating blockchain technology on students' career development within the database system field, including potential job opportunities and skill enhancement.	4.20	0.43	High	
Ease of Use Criteria Assessment	The simplicity of blockchain technology for students in vocational education, in ensuring ease of use.	4.71	0.44	High	2
	Effectiveness of blockchain technology in improving learning outcomes.	4.55	0.50	High	
	Blockchain technology helps in overcoming challenges and maximizing student understanding.	4.41	0.48	High	
Access Assessment Criteria	How easy it is for students to access blockchain technology tools and platforms	4.76	0.41	High	3
	Is the blockchain technology integrated with the learning management system	4.30	0.45	High	
	How secure is the blockchain technology	4.20	0.40	High	
	Whether blockchain technology can be accessed and used anytime and anywhere	3.55	0.87	Mid	

Since the emergence of blockchain technology, in fact, its use is still minimal in the education sector, especially in the context of vocational education in Indonesia, especially in learning database systems [34]. Only a few studies have discussed the benefits of blockchain technology for education [35], [36]. In line with this statement, most research still focuses on the development of blockchain technology [4], [3], [37]. This study is the first step in experimental research to evaluate the impact of this innovative technology on the education system in Indonesia, with a particular focus on its effect on student performance in database system learning.

This research has two main objectives: first, to assess the extent of blockchain technology's impact on student performance in database systems, and second, to understand student responses to blockchain technology related to usability, utility, and accessibility, in the hope of improving overall learning outcomes. The expectation is that blockchain technology will have a significant positive impact on improving student learning outcomes in database systems subjects. The results of data analysis from the database system learning outcomes test showed a significant difference between the mean scores for the pre-test (43.81%) and post-test (46.52%) effect sizes. This indicates a significant improvement in database system learning outcomes after the integration of blockchain technology.

From the results of the study, several factors can be attributed to the improvement of learning outcomes in the database systems course. First, the implementation of the intervention using blockchain technology was successful, allowing educators to use blockchain simultaneously with face-to-face sessions and upload relevant resources according to the database system material. Second, the use of blockchain technology for 16 meetings in the learning program had a positive impact on the learning outcomes of vocational education students. Third, the blockchain technology platform is easy to use and understand by students. In line with the results of previous studies explaining that the use of blockchain technology supports the development of the education system [14], [38], the conclusion of this study shows that the use of blockchain technology in the education system in Indonesia, especially in vocational education, is rated favorably by students in terms of simplicity of use, usability, and accessibility aspects for database system learning. The application of blockchain technology to learning is also explained by research [39], [40], [25], which shows the effectiveness of blockchain technology in improving learning outcomes in database system courses and increasing the involvement of vocational education students in the learning process.

This study also analyzed the results of students' assessment of the use of blockchain technology, which received positive responses in the aspects of usability, ease of use, and accessibility. Based on the analysis of research data, vocational education students gave the highest assessment on the usability aspect of blockchain technology, followed by an assessment of the ease-of-use aspect, and the accessibility aspect received an assessment in the third position from the results of student responses. This study is in line with the findings of previous research [41], [42], which also showed a positive response to the use of blockchain technology in education. The conclusion of this study shows that the application of blockchain technology reflects the development of the utilization of renewable technology [15], [43] in the field of education in Indonesia. The implications of the results of this study are expected to provide opportunities to improve the effectiveness of database system learning in vocational education. Responses from research respondents stated that the use of blockchain technology is very useful in improving learning outcomes and providing more innovative learning options, with the aim of developing the learning system in Indonesia.

Furthermore, previous research has supported the positive impact of using blockchain technology in the context of vocational education [11], [44], showing that it can successfully provide recommendations to improve the effectiveness of the learning process so that students become more active. In general, the majority of blockchain technology users are satisfied with its utilization [45]. Furthermore, the features offered by blockchain technology can be implemented in the learning process and successfully improve the learning outcomes of database systems in the field of vocational education in Indonesia, as shown in the case study in the department of informatics engineering education and informatics engineering. The positive response

from students and lecturers to the use of blockchain technology is also an indication of the success of this implementation. The results of these responses overall show an improvement in the performance of student learning outcomes. Therefore, understanding the purpose of using renewable technology in the learning system in Indonesia is very important. In addition, knowing how to effectively implement renewable technologies, such as blockchain, can help improve the teaching and learning process.

4 CONCLUSIONS

The integration of blockchain technology into the learning system of vocational education in Indonesia has shown promising results in enhancing the effectiveness of database system learning outcomes. This research, focusing on students in Informatics Engineering Education, aimed to evaluate the impact of blockchain technology on student performance and perceptions. The findings indicate a significant improvement in learning outcomes, as evidenced by the analysis of pre-test and post-test scores. The effect size, with a substantial increase of approximately 46.50%, emphasizes the positive influence of blockchain technology on student achievements in the database system course. Moreover, the assessment of student responses to usability, usefulness, and accessibility aspects after the adoption of blockchain technology revealed positive feedback. Students acknowledged the ease of use, practical applications, and improved access to learning resources facilitated by blockchain integration. The study also introduced key criteria for evaluating the effectiveness of blockchain technology in the learning system, encompassing relevance to learning objectives, enhancement of learning experience, practical application in the industry, facilitation of conceptual understanding, integration with the curriculum, alignment with technological advancements, feedback and evaluation mechanisms, collaborative learning opportunities, and accessibility and user-friendliness, in line with research [11]. The positive outcomes of this research align with the global trend of incorporating innovative technologies into education [15], [42]. The implications extend beyond individual student performance, reaching educational institutions, policymakers, and educators [35], [41]. The successful integration of blockchain technology in vocational education contributes to the ongoing discourse on optimizing technology-enhanced learning [13], [14]. This study utilized a mixed-methods approach, combining quantitative and qualitative data, to provide comprehensive insights into various aspects of blockchain technology implementation. The presented conclusions aim to guide future endeavors in leveraging technological advancements for further improvements in the learning systems of vocational education in Indonesia.

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6 AUTHOR CONTRIBUTIONS

Muhammad Hakiki: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Software; Visualization; Writing—original draft; Writing—review & editing. **Radinal Fadli:** Formal analysis; Investigation; Software; Writing—original draft; Writing—review & editing. **Arisman Sabir:** Validation; Data Curation; Writing—original draft, Writing—review and editing. **Agung Prihatmojo:** Data curation; Formal analysis; Writing—original draft; Writing—review & editing. **Yayuk Hidayah:** Validation; Data Curation; Writing—review and editing. **Irwandi:** Data curation; Formal analysis; Writing—original draft; Writing—review & editing.

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