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Emerging Technologies for Sustainable Universities and Colleges: A Meta-Synthesis

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ABSTRACT

Sustainability is a key concern in modernizing higher education. This paper reviews how emerging technologies are integrated to promote sustainability in universities and colleges, analyzing various technologies, benefits, drivers, and barriers using the STARLITE framework. Key technologies include web and internet technologies, online assessment systems, green computing, advanced data analytics and AI tools, smart infrastructures, Bluetooth beacons, digital transformation, e-Learning/LMS, simulation-based education, gamification, and MOOCs. These technologies enhance student learning outcomes and campus efficiency. Successful integration requires strong leadership, relevant curriculum, and stakeholder involvement. Barriers include technological issues, misconceptions of sustainability, lack of financial resources, and stakeholder apathy. Institutional leaders play crucial roles in aligning goals towards sustainability with these technologies.

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1. INTRODUCTION

In an era characterized by unprecedented global challenges, higher education institutions must reevaluate and fortify their foundations to ensure long-term viability. Integrating emerging technologies in higher education to accelerate digital transformation has become necessary to optimize hybrid learning environments and continuously adapt to the changing world. There has been a growing need to recognize that this shift is essential for optimizing hybrid learning environments and adapting continually to the evolving global education landscape.

Rof *et al*. (2022) noted that educational institutions are realizing the necessity of establishing a resilient education system, prompting them to embrace digital transformation, incorporate technology in classrooms, and immerse themselves in virtual and remote education. HEIs also represent a crucial stakeholder in the promotion and implementation of the United Nations (UN) 2030 Agenda for Sustainable Development (Vallez *et al*., 2022) and the adoption of digitalization in the society green towards social innovation (Carayannis & Morawska-Jancelewicz, 2022). This transformative journey extends beyond students, involving key stakeholders as various emerging technologies are being explored as potential solutions, holding the promise to address and mitigate challenges (Ahalt & Fecho, 2015).

This implies that emerging technologies and sustainability are crucial to the longevity, survival, and sustainable operations of higher education institutions. Therefore, HEIs should support sustainable development in their physical infrastructure, decision-making processes, and pedagogical issues (Fuchs *et al*., 2020) to guide actions toward sustainability throughout the entire university system, which includes the campus operations and services of the institution. Furthermore, the integration of emerging technologies has become imperative not only to enhance the learning experience but also to streamline administrative processes, reduce costs, and ensure the sustainability of these institutions.

In Klempin and Karp (2005) perspective, the enduring success of a university does not stem from a steadfast resistance to change but, instead, derives from its capacity to undergo evolution, adaptation, and transformation over time. Hence, the ability to embrace and navigate change is a crucial factor contributing to a university's longevity, suggesting that institutions must be dynamic and responsive to evolving educational, societal, and technological settings to thrive in the long run. As the world becomes increasingly interconnected, the demand for innovative educational approaches that transcend geographical boundaries has intensified.

On the other hand, the current higher education systems have been facing great challenges to be able to afford recent technological developments along with the complexity of this innovation that the future generation needs to adapt. Therefore, to explore the multifaceted aspects and benefits of technology integration in universities and colleges that contribute to their sustainability, the researchers identified the types of emerging technologies, determined the drivers and barriers to implementing technologies, and recommended ways to create a sustainable institution. This study will add to the current literature on how these emerging technologies are integrated towards the sustainability of colleges and universities especially those institutions gearing towards sustainability champions at par with the other world-class higher educational institutions.

This study sought to determine the types of emerging technologies that are integrated into universities and colleges to ensure sustainability, identify the benefits of emerging technologies, and present the drivers and barriers to implementing technologies.

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2. METHODS

The study employed meta-synthesis to determine the emerging technologies integrated into universities and colleges to ensure their sustainability. Furthermore, the process included framing the research question, setting the exclusion and inclusion criteria, selecting the related studies, assessing the quality of these journal articles, extracting the data, analyzing the data, and expressing the synthesis. The primary data sources are research articles about the emerging technologies integrated by universities and colleges collected from different online resources.

Moreover, the article screening process was facilitated using the framework STARLITE (Booth, 2006) to convey the essential elements for reporting literature searches. Eligibility criteria included worldwide research articles on emerging technologies integrated by universities and colleges in the past six years, focusing on their contribution to sustainability as to economic and environmental impacts, longevity, survival, and ability to sustain the operations of universities and colleges. The information sources are Google Scholar and other sources with multidisciplinary research articles or journals. The search strategy included keyword filters such as systematic analysis, meta-synthesis, emerging technologies, and sustainability of universities and colleges. The selection process involved determining the number of articles screened, included, excluded, retrieved, not retrieved, assessed for eligibility, and reasons for exclusion. To ensure data quality and accuracy and reduce the risk of biased assessment independent reviews of the research team were done, after screening, out of 152 publications, 18 studies qualified for meta-synthesis, and 33 were considered for related literature and supporting studies. In analyzing the qualitative and descriptive data, thematic analysis using a deductive approach was employed.

3. RESULTS AND DISCUSSION

3.1. Emerging Technologies Integrated into Universities and Colleges

Emerging technologies are those technological advancements that give teachers and students a competitive edge in a particular subject. The findings of Sun (2020) showed a generally positive relationship between the use of learning technology and student engagement and learning outcomes. As contemporary network technology advanced, people started utilizing it for educational purposes, and college English instruction is no different. This led to the steady development of the online learning system concept. Ensuring the quality of students' learning, optimizing the learning environment and behavior, and establishing an effective connection with the offline learning system are all possible with this system. Therefore, the system can be considered in the sustainability of the institution as supported by the findings of Daniela *et al*. (2018) that there is an urgent need to support the development of stakeholders' digital competence to ensure sustainable higher education, which is a great challenge in the transformative processes of higher education systems around the world.

The shift toward online learning solutions has grown since the pandemic's emergence. One of the necessities is the development of an online assessment system. Remotely proctored exams are one of the most contentious topics in academic integrity and even in the broader field of education (Gudiño *et al*., 2021). Proctored online assessments are expected to become more prevalent in education since test takers and users are drawn to the flexibility of testing from anywhere at any time. Hence, higher education institutions are urged to develop online assessment systems. Remote proctoring has its pros and cons, and the

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insufficient data about the effectiveness of remote proctoring in detecting cheating points to its potential ineffectiveness, but strong evidence supports the deterrent effect of the practice.

Green computing technology pertains to green IT which is designed, manufactured, used, and disposed of in a manner that consumes minimal energy and is environmentally friendly (Vakaliuk *et al*., 2020). IT-regulated smart energy management systems, such as sensor-based lighting and heating boost energy efficiency. HEIs can use these systems, which monitor and control the energy consumption on the campus, hence, reducing energy waste. IT can also help to conserve tangible resources, such as paper; digital document management systems limit the need for hard copy documents and promote efficiency in campus operations (Cavicchi, 2021; Chebeň *et al*., 2020). Integrating these types of technologies can greatly help institutions to reduce their carbon footprints. However, knowledge of such technologies in HEIs is limited, and more strategies are needed to increase the use of such technologies within HEIs (Dhaini *et al*., 2021; Vakaliuk *et al*., 2020). Moreover, IT can support sustainability in HEIs by reducing e-waste promoting efficient energy use, and the responsible disposal of used electronic equipment. For example, using virtualization technologies can reduce the number of physical servers required, thereby reducing energy consumption (Smith & Johnson, 2018).

Big data technologies, such as advanced data analytics and AI tools, can greatly help with gathering and analyzing large amounts of data. This data can then be used to understand the patterns and trends necessary to address the problems related to the successful implementation of sustainable development in any institution (Ojokoh *et al*., 2020). This is supported by the findings of Leal Filho *et al*. (2023) which explored the various ways that data science and AI could support HEIs' efforts toward sustainable development. The researchers stated that the deployment of these technologies leads to sustainable knowledge gains. Hence, these technologies facilitate the analysis of large amounts of data related to energy consumption. helping HEIs to reduce waste, optimize their energy usage, and use physical resources judiciously.

Smart infrastructure includes optimizing university campuses with intelligent building systems to improve sustainability (Bracco *et al*., 2018). Universities and colleges can improve their energy consumption by installing technologies that automatically control lighting, heating, and cooling systems. To Fraga-Lamas *et al*. (2029), these types of technologies are comparable to those used in smart cities powered by Internet of Things (IoT) networks. If deployed, they can turn physical learning spaces into smart campuses that enable them to gather information and network with the users of the campus or students. The deployment of such networks can enhance the sustainability of institutions' operations as suitable places for learning, as well as increase energy and water efficiency, reduce waste management, and increase sustainability (Trevisan *et al*., 2023).

Considering the surge in e-learning growth over the last decade and the proliferation of mobile devices in the Bring Your Own Device generation, Griffiths *et al*. (2019) review selected use cases of Bluetooth beacons in educational situations. They discussed the trial placement of Bluetooth beacons at the Hong Kong Polytechnic University, Hong Kong, to develop physical learning spaces, and they examined the role that beacons play in mixed pedagogies, which combine digital and physical learning spaces. A similar study was conducted by Matuska *et al*. (2023) who presented the design and implementation of a functional IoT-based connected university system—a robust and massive IoT Bluetooth beacon system for integrating various services as subsystems. Though beacon systems in education are used for checking attendance and distribution of learning materials for taking attendance and distributing instructional materials, this technology is not widely adopted by educational institutions.

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Digital transformation (DT) can support sustainability in higher education institutions (HEIs). Trevisan *et al*. (2023), suggested three areas of current research: ensuring sustainability competencies through DT, smart and sustainable campus approaches, and theorization of sustainability in higher education through DT. From this standpoint, HEIs can not only enhance collaborative learning about sustainability but also foster cross-cultural awareness, facilitate virtual student mobility, enhance students' knowledge about sustainability, and empower them to become responsible citizens who are well-equipped to deal with the global challenges of the future.

The Learning Management System (LMS) is a seamless method for continuing education during the COVID-19 pandemic. Chaubey and Bhattacharaya (2015), pointed out the role of the LMS in teaching and learning pedagogy, access and flexibility, and cost-effectiveness in higher education, they suggested higher education institutions integrate the LMS into their teaching and learning process to achieve effective learning outcomes. Indeed, LMS enables users to have meaningful learning experiences with their diverse learning styles and motivates these individuals to be lifelong learners with the help of the current technology.

Simulation-based education (SE) describes the enrichment of teaching and learning processes. As a result, it is essential to give students the appropriate training and equip them with the analytical abilities they will require for creating, putting into practice, and operating these systems. Simulation in education provides an effective way to support instructors during the training process since simulation allows for realistic models that students can employ during their learning activities (Campos, 2020). While educators have promoted the use of serious games and simulations in education for sustainability, more experimental study is required to determine how these active learning techniques affect students' attitudes, knowledge, and abilities (Chatpinyakoop *et al*., 2022).

Video games, game-based learning, and gamification are some of the popular methods teachers are using to provide sustainable education in the classroom. These methods and tools have evolved into new approaches that improve the education process. The study of Gatti *et al*. (2019) suggested that the action learning approach, and in particular, simulation and gaming, may successfully generate cognitive and affective learning outcomes which in turn may affect students' development of critical thinking skills. This innovative way of enhancing the learning experiences of the students helps them to improve their academic performance.

Alyoussef (2021) narrowed the gap in the literature on the adoption of massive open online courses (MOOCs) and the role of task-technology fit (TTF), which influences student satisfaction, academic performance, and sustainability of MOOCs in higher education. The outcomes showed that social influence, perceived usefulness, and perceived ease of use all positively correlated with task-technology fit and the usage of MOOCs as a sustainable teaching strategy in higher education. Hence, students' enjoyment and academic performance were positively impacted by the function that MOOCs and TTF had in the sustainability of education. Therefore, to guarantee MOOCs' long-term viability (sustainability), higher education institutions should promote the usage of MOOCs in their curricula.

The world is changing, and technology is rising, and this change is adopted by colleges and universities. Innovative methods and cutting-edge technology have been created throughout the ages. While some of these technologies are the result of commercial research and development, others are the result of theoretical research. The presentation above is just a few of the emerging technologies nowadays, and over time these technologies are

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continuously evolving. The challenge for institutions and educators is to utilize these technologies responsibly to sustain institutions and education in general.

3.2. Benefits of Emerging Technologies

Universities and colleges are continuously discovering innovative ways to enhance the pedagogical experiences of the students. These innovations accompany digital transformation to be able to cater to the needs of the institution for its development. The recent technologies used by these institutions help them sustain their operations while also considering not only the learners but also the economy and the environment.

The online learning environments foster additional learning experiences where learners can interact, collaborate, and take ownership of their learning at their own pace and time. When there is a shift from a teacher-controlled environment to a more learner-controlled environment, the role of the educator becomes more of a facilitator and minimal scaffolding may be required (Geng *et al*., 2019). Moreover, the challenges brought by COVID-19 have urged the teachers, students, and administrators to adopt online modality of learning despite of unpreparedness of the many institutions and its possible loopholes in the implementation phase. Similarly, many universities had to cease their operations or continue education through distance and remote learning. Some universities in China like the New York University Shanghai, and Duke Kunshan University successfully adopted educational technology products like Zoom and Moodle which are video-conferencing platforms. Significantly, these universities with these technological experiences were able to expand and were not starting from scratch with new and untested tech solutions (Czerniewicz, 2020).

Nevertheless, the positive attitude towards the integration of technology in teaching is pivotal. Hence, students may easily access educational information through digital learning and learning management systems at their own pace. During the COVID-19 pandemic, many universities and colleges shifted to online learning through LMS which became the source of sustainability during the closure of some universities and other educational institutions. Alturki and Aldraiweesh (2021) claimed that the virtual format leads to significant energy savings, reduction in paper usage, elimination of student mobility, and allows HEIs to deliver sustainability-focused education.

Furthermore, Massive Open Online Course (MOOC) is also an emerging technology that is now offered by HEIs. There are foreign universities that offer MOOCs like Stanford University, Harvard University, and Yale University. Comparatively, some universities in the Philippines like the University of the Philippines Open University and De La Salle University's Lasallian Open Online Course offer MOOCs. As a result, the use of MOOCs in learning processes should be encouraged in higher educational institutions to ensure their sustainability (Alyoussef, 2021). Moreover, Abhishek *et al*. (2023) provide evidence that MOOCs are positively influencing learning efficiency and also can be employed in a blended model of education to promote collaborative learning.

Higher Education Institutions also use digital technologies, advanced data analytics, and AI tools which help in processing vast amounts of data at an improved speed and accuracy to simplify tasks that can help HEIs in their operations. Through digital transformation and sustainability activities, HEIs can work together to face global challenges by educating responsible citizens and disseminating a sustainability culture throughout the university system (Trevisan *et al*., 2023). Internet-based proctored assessment or Online Proctored Examination is one example of digital technologies commonly used by HEIs. This protects score integrity and test content. This also helps in minimizing cheating and unauthorized behavior. The use of live and AI remote proctoring minimizes cheating, secures test content,

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and provides comparable score distributions (Langenfeld, 2020). Universities like Arizona State University, USA and California State University, USA use online proctored examinations. Relatively, Kubiatko (2020) highlighted that automated proctoring allows an online examination as to the preference of the examinee while being monitored at the same time. Consequently, testing organizations need to ensure careful evaluation of privacy issues and develop policies that will secure the private information of the test takers which may be put at risk.

Digital technology in universities is also helpful in incorporating video games, gamification, and game-based learning. It also promotes various social skills like collaborative and cooperative work. Gamification and game-based learning favor education for sustainability, and they promote educational inclusion and the work of various social skills, such as collaborative and cooperative work (Pineda-Martínez *et al.*, 2023). It can be gleaned from the literature that employing game-based learning is beneficial in facilitating the understanding of the contents, the engagement of students, creativity and innovation, and social competence. Some foreign universities and colleges use gamification like Indiana University with their Virtual Experience Lab, Boston's Emerson College's Engagement Game Lab, and the Games Research Lab at Teachers College of Columbia University. Campos *et al*. (2020) claimed that simulation education software, tools, and games constitute an excellent methodological option to support instructors during the training process since simulation allows for realistic models that students can employ during their learning activities. Simulation technology helps in increasing students' motivation. It also fosters collaborative or cooperative work as well as the decision, critical thinking, and problem-solving among students. Easy integration of simulation education resources with blended and online courses promotes expansion and popularity among universities and training centers globally. As a result, students improve their interdisciplinary skills, teamwork abilities, and multicultural learning.

The emerging technologies are not only beneficial for the learners but also for the environment. The smart infrastructure at the University of Genoa in Italy at Savona Campus is one example that optimizes energy consumption by deploying technologies that automatically control lighting, heating, and cooling systems (Bracco *et al*., 2018). Undeniably, it resulted in economic savings that helped strengthen the sustainability concept within the campus. Another environmentally friendly technology used by HEIs is the Green Computing Technology. This reduces the use of computers and helps reduce carbon emissions. Arizona University and Hampshire College are into green computing. This also helps the HEIs in cutting the costs of purchasing licensed software and ca be used to keep all different electronic files.

Bluetooth beacons are also adapted by HEIs. This is very useful in e-learning; they support efficiency by saving time and reducing workload as well as eliminating the need for physical copies of information. The minimal energy consumption of personal locator beacon contributes to the sustainability impact of a beacon system that even deploying a significant number of beacons will not significantly affect the overall power usage of a project unless settings such as the transmission power are increased, reducing the overall battery life (Griffiths *et al*., 2019).

3.3. Benefits of Emerging Technologies

The need to integrate emerging technologies can be possible through the strong leadership of the university, strong involvement of stakeholders, and a well-designed curriculum aligned with personalized support for the students as well as alleviating teacher workload. However, due to the limited access to these technologies, probabilistic outcome sustainability, no

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support from the top management in utilizing the resources and facilities, lack of financial support, and public concern, these institutions are facing great challenges toward their goals of sustainability along with changing time and keep apar with other sustainability champions.

There are various reasons for the use of emerging technologies for sustainability in universities. Weiss *et al*. (2021) confirmed that implementing technologies is associated with strong leadership by the university; incentives and support through professional development; concurrent implementation of sustainability in research, campus operations, and outreach; and formal involvement of internal and external stakeholders as well as sustainability champions, among others. Strong leadership encourages the adoption of new technologies for it will help in the progress of the entire institution. Similarly, the professional development of the faculty enhances their skills and competencies in employing these technologies in curriculum implementation. Relatively, conducting research requires the use of research centers equipped with these innovations that can be used to improve the institution as well as the extensive development of various projects or programs and extension activities. Similarly, these technologies will be of great help in collaboration with other partners, especially with those other higher educational institutions that are already established. These drivers are huge forces enabling higher educational institutions to embrace these changes towards sustainability.

Wang *et al*. (2023) also cited in their study that the most significant drivers for the implementation of digital transformation in HEIs in the era of Industry 4.0 are developing, updating, and adapting a curriculum integration of digital technologies for universal education and cloud computing, respectively. Each university needs to be abreast with the current technologies that cater to the needs of the students in the present age of modern technology and be globally competitive with other higher educational institutions. The need to adapt to the changes is necessary to continuously align the curriculum to its sustainability through digital transformation.

Similarly, the study of Chugh *et al*. (2023) found the dynamic interplay of educational technology characteristics, stakeholder perceptions on the effectiveness of technology integration decisions, theoretical frameworks, and models relevant to technology integration in teaching, and assessment to creating viable pathways to effective educational technology implementation. Indeed, the study designed a framework that will focus on the development of feasible strategies anchored on the five dimensions which are the technology, stakeholders' insights, academic subjects, success standards, and research. This framework would guide the institution to design and plan effective strategies to integrate this technology successfully.

Also, Sembey *et al*. (2023) found out that the major intent of integrating emerging technologies (ETs) that emerged from the synthesis was to analyze the learning performance of students to develop more personalized support promptly and alleviate teacher workload. The need to integrate these technologies in the curriculum implementation will cater to the needs of the students for them to perform well academically and maximize the learning experiences in the 21st century. Additionally, it will make the various tasks of the teachers easier through these ETs and be more productive which can greatly impact to development of the institution. Hence, these roles of the ETs pave the way for colleges and universities to embrace this development and take necessary steps to align the goals towards sustainability by keeping at par with other higher educational institutions (HEIs).

Conversely, numerous studies examined the aspects that serve as barriers to implementing technology for sustainability in higher education. Gkrimpizi *et al*. (2023) cited in their study that technological barriers like lack of adequate IT infrastructure, integration of digital

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technologies in educational systems, security and privacy risks, data fragmentation, and legacy systems and third-party systems can affect the digital transformation of HEIs, limiting their ability to embrace and effectively use digital technologies so that the organization can operate seamlessly; all services are now, to a large extent, enabled by technology. Indeed, these factors impede the digital transformation among universities and colleges especially those institutions not equipped with adequate resources during the implementation. The need to focus on this barrier should be taken into consideration through the proper allocation of funds intended for the provision of these technologies to be able to sustain the operation and services of the institution.

Relatively, the study of Alhazmi *et al*. (2023) revealed that the major hindrances in the sustainability of HEIs that were identified are a lack of understanding about the subject and conflicting opinions about the concept of sustainability held by various HEI stakeholders. Also, there is evidence that the top management of HEIs can sometimes be unwilling to initiate sustainability initiatives, though this could reflect a lack of financial resources needed to implement sustainability schemes. These situations impede the organizational culture of sustainability within an organization. In an institution, the need for collaboration in the successful implementation of the programs and projects will be necessary. Hence, through partnerships and common goals, there could be sustainability.

4. CONCLUSION

This research aimed to determine the emerging technologies integrated by universities and colleges that contribute to their sustainability and the study found out that some of the emerging technologies that universities and colleges integrate into their systems for sustainability are as follows: Web and other Internet technologies, Online assessment delivery systems, Green Computing Technologies, Advanced-Data Analytics and AI tools, Smart infrastructures, Bluetooth Beacons, Digital Transformation, E-Learning/Learning Management Systems, Simulation-based education, Gamification, and Massive Open Online Course (MOOCs).

The integration of emerging technologies in universities and colleges has changed the landscape of education and sustainability. Web allowed lessons to be delivered without physical interaction, offering learners the flexibility to study more effectively; assessment strategies continue to evolve; green technology reduces costs associated with licensed software and efficiently managing electronic files; advanced data analytics and AI tools improved data processing speed and accuracy, simplifying tasks; smart infrastructures reduced energy bills, promoting economic savings and sustainability; Bluetooth beacons proved valuable in e-learning, enhancing efficiency by saving time and reducing workload, eliminating the need for physical copies of information; digital transformation contributed to the continuity of teaching and learning processes, linking it to sustainability in higher education to address global challenges; e-learning and LMS conserved resources and time, providing students with easy access to educational information regardless of time constraints, and reducing mobility; simulation-based education increased student motivation, fostered collaborative work, and enhanced decision-making and critical thinking skills; game-based technology in education promotes sustainability and social skills; and MOOCs offered flexible learning, allowing learners to access courses at their own pace, leading to increased satisfaction and academic performance. The success of sustainable initiatives in universities and colleges is driven by strong leadership, complemented by incentives and support through professional development. Effective sustainability implementation involves the simultaneous integration of sustainability practices in research, campus operations, and outreach efforts,

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strengthened by partnerships with internal and external stakeholders, as well as the presence of sustainability efforts within the institution. On the other hand, the barriers to full utilization of emerging technologies are the following: lack of adequate IT infrastructure, integration of digital technologies in educational systems, security and privacy risks, data fragmentation, and legacy and third-party systems.

Some higher education institutions have transformed their systems by adopting smart technologies that have implications for operations and research and these actions help fulfill sustainability goals. Recognizing the value of the role that technology plays in promoting sustainability it is recommended that higher education institutions may incorporate the relevant emerging technologies into their operations towards the goal of the higher educational institutions to achieve sustainability.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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