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LEARNING ABOUT INORGANIC CHEMICAL FUNCTIONS BY IMPLEMENTING eXeLearning AS AN EDUCATIONAL STRATEGY[a]

EL APRENDIZAJE DE LAS FUNCIONES QUÍMICAS INORGÁNICAS MEDIANTE LA IMPLEMENTACIÓN DE eXeLearning COMO ESTRATEGIA EDUCATIVA

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ABSTRACT: Over time, the teaching of chemistry has gained importance due to the need to foster and stimulate learning of the processes encompassed by this discipline. Additionally, its interrelation with other areas such as biology, physics, and even mathematics is acknowledged. Therefore, the teaching of inorganic chemical functions plays a fundamental role in the learning process of chemistry as a natural science. The main objective of this research project was to design a didactic strategy to strengthen the understanding of inorganic chemical functions using the eXeLearning computer tool, targeted at tenth-grade students at Colegio Católico Baltasar Álvarez Restrepo. A mixed methodology with a descriptive approach was employed. To achieve the proposed objectives, a pretest was conducted, followed by the implementation of the pedagogical intervention with the educational strategy, and finally, a posttest was carried out to assess students' progress. The results allowed for the identification of the level of learning using the Hake factor, in which the control group showed an average value of (0.5), and the experimental group obtained a high factor (0.8). In conclusion, the application of the educational strategy through the eXeLearning software facilitated significant learning of the proposed subject matter during the teaching of inorganic chemical functions..

KEYWORDS: Curriculum development; educational technology; eXeLearning; hake factor; inorganic chemistry.

RESUMEN: A lo largo del tiempo, la enseñanza de la química ha adquirido importancia debido a la necesidad de fomentar y estimular el aprendizaje de los procesos que esta disciplina abarca. Además, se reconoce su interrelación con otras áreas como la biología, la física e incluso las matemáticas. Por lo tanto, la enseñanza de las funciones químicas inorgánicas desempeña un papel fundamental en el proceso de aprendizaje de la química como ciencia natural. El objetivo principal de este proyecto de investigación fue diseñar una estrategia didáctica para fortalecer la comprensión

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de las funciones químicas inorgánicas utilizando la herramienta informática eXeLearning, dirigida a estudiantes de décimo grado en el Colegio Católico Baltasar Álvarez Restrepo. Se utilizó una metodología mixta con un enfoque descriptivo. Para lograr los objetivos propuestos, se llevó a cabo un pretest, se implementó la intervención pedagógica con la estrategia educativa y, finalmente, se realizó un postest para evaluar el progreso de los estudiantes. Los resultados obtenidos permitieron identificar el nivel de aprendizaje mediante el uso del factor de Hake, en el cual el grupo de control mostró un valor promedio de (0,5) y el grupo experimental obtuvo un factor alto (0,8). En conclusión, la aplicación de la estrategia educativa a través del software eXeLearning facilitó un aprendizaje significativo de la temática propuesta durante la enseñanza de las funciones químicas inorgánicas.

PALABRAS CLAVES: Desarrollo curricular; tecnología educativa; eXeLearning; factor de hake; química inorgánica; nomenclatura.

1. INTRODUCTION

Alchemy as a precursor of chemistry, implied a taboo at that time where the advance of science was limited to empiricism and the knowledge that little by little was being forged among the beings that inhabited the Earth. The emergence of fire is a clear example of a before, and after for the development of chemistry as a science (Salas Peregrín & Capitán Vallvey, 2018). In this sense, a new knowledge begins to be built that derives from the need to determine a scheme, a symbology and some parameters typical of that discovery that over time began to nourish what is now known as chemical sciences. In the first instance, man recognizes the importance of chemistry as an experimental science and subsequently identifies its importance for the development of other sciences and humanity (Largo-Taborda & Hurtado-Vinasco, 2024; Valencia-Giraldo, 2002).

From there, the learning of chemistry becomes increasingly complex as new elements start to appear, and new projects are generated focused on the discovery of new compounds (Olivares Campillo, 2014). However, chemistry begins to have its peak when it begins to be implemented to consolidate the development of society, it is there where its importance is internalized by relating to various areas such as health, science, geology, biology, physics and even education (Santos, 2010). In the field of education, the teaching and learning of chemistry is perhaps considered one of the subjects that presents greater difficulty in addressing those concepts that are specific to it. For example, stoichiometry, nomenclature, reactions and chemical bonds are some of the topics that require adequate preparation and knowledge to understand their importance (Olivares Campillo, 2014).

Another example is the inorganic chemical functions which are related to stoichiometry, reactions and especially to nomenclature (Guyton de Morveau, 1788). This topic requires attention since there are 4 types of inorganic chemical functions (oxides, acids, bases and salts) and in turn 3 types of nomenclatures, that is, 3 different ways of naming compounds (Gómez-Moliné *et al.*, 2008). On the other hand, information and communication technologies (ICT) have directly permeated education since they have made it possible to transform training processes by providing tools that facilitate the teaching of subjects by changing the way in which, when and, where you can teach (Gutiérrez *et al.*, 2018; Parra Bernal & Rengifo Rodríguez, 2021; Parra-Bernal, 2020).

Given the above, the use of educational software such as eXeLearning allows modifying aspects of the educational environment which have been anchored to traditional processes and which currently demands a change in the educational paradigm from educational innovation (Parra Bernal & Rengifo Rodríguez, 2021). Additionally, it allows students and teachers to find a point of intersection between what they want to teach and how they learn in times when technology is greatly acceptance by society (Largo-Taborda & Rosero-Moreano, 2016).

2. METHODOLOGY

This research project unfolded within the academic setting of Baltasar Álvarez Restrepo Catholic College, situated in the city of Dosquebradas, Risaralda. Catering to both primary and secondary students spanning from transition grade to eleventh grade, the institution served as the backdrop for the investigation. The focus of this study was directed towards the tenth grade, specifically encompassing two distinct groups, namely 10 A and 10 B.

In adherence to a comprehensive research approach, a mixed methodology was employed to facilitate a qualitative exploration of the educational subject. Concurrently, the research aimed to scrutinize the outcomes generated by pretest and posttest evaluations through the utilization of the Hake Factor (Castañeda *et al.*, 2018). This factor was instrumental in quantifying the learning gain derived from the implementation of a didactic strategy employing the eXeLearning software for the instruction of inorganic chemical functions.

It is crucial to acknowledge the active participation of a total of 40 students, with each group consisting of 20 tenth-grade students. The research design involved the administration of a pretest before the initiation of the inorganic chemical functions' topic. Subsequently, following the application of the educational strategy, a posttest was employed to gauge the progress of students about the concepts covered in class (Duque-Cardona & Largo-Taborda, 2021).

The chosen educational tool for this endeavor was the eXeLearning software, strategically implemented in classes dedicated to teaching inorganic chemical functions. The software was instrumental in executing a variety of activities and didactic strategies tailored to support the instructional process for the experimental group (10 B) in comparison to the control group (10 A). This approach aimed to provide a nuanced understanding of the software's impact on learning outcomes in the context of inorganic chemical functions.

As for the design and construction of the pretest and the postest, a total of 15 questions were applied, which can be answered by multiple choice or open, the topics that were sought to evaluate in this were: oxides, hydroxides, acids and salts. From this, the questions are focused on the formation of chemical compounds by identifying and using inorganic chemical functions, types of oxides, acids and salts, as well as nomenclature for each function, as established by IUPAC.

The educational proposal was applied for half a school year, that is to say two academic periods based on the curriculum structure of the educational institution and considering that students have training in chemical sciences from the eighth grade. It is important to emphasize that the 40 students were former students in the institution and therefore recognized chemistry concepts which favored the implementation of eXeLearning for teaching inorganic chemical functions.

However, data collection was carried out through participant observation as the students developed the activities proposed in the classroom, In addition, the dialogue and interaction regarding the issues of inorganic chemical functions and the results of different activities designed on the platform were taken into account. Based on the observations, an analysis of the different interactions between the teacher and the student was made, as well as the collaborative work and the resolution of the proposed exercises each time each chemical function was addressed.

The results of the tests and activities were recorded in such a way that it was possible to carry out the comparative exercise between the pretest and the postest with the purpose of recognizing the learning gain by means of the Hake factor in order to identify the contribution made by design of proposed activities with the eXeLearning digital resource.

3. RESULTS

3.1. Analysis of the Pretest

For the interpretation of the results, the initial or pretest test that was applied for both groups was taken into account to recognize those concepts characteristic of inorganic chemical functions such as: oxides, acids, bases and salts and the types of nomenclature to name, that is, to identify if students know the rules established by the IUPAC (International Union of Pure and Applied Chemistry) to name the chemical compounds.

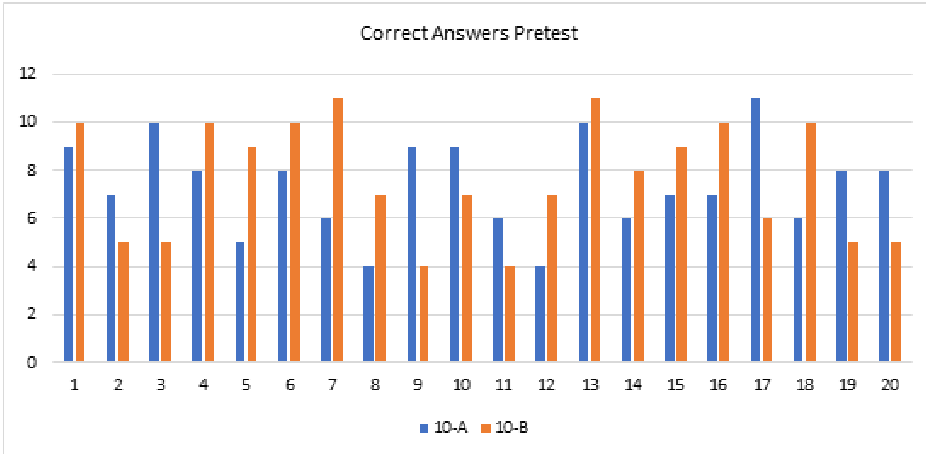

Figure 1: Correct pretest answers for the control and experimental groups. Source: Author's Own Work.

In this regard, the pretest results for both groups are presented in Figure 1. There we can show the number of correct answers that they had once applied the questionnaire with 15 questions where we investigated concepts and procedures related to inorganic chemical functions and their nomenclature.

Once the pretest is applied, the virtual space is designed in the free software eXeLearning which allows the design of activities and content which can be linked to other ICT tools that facilitate the approach of the topics, in this particular case the inorganic chemical functions are worked, that means, oxides, acids, bases and salts. For each case, an interactive space was built in which students had access to resources such as infographics, videos, and digital content, among other options in order to promote the learning of chemistry from innovative and didactic processes.

3.2. Analysis of postest

Once the educational strategy was applied through the use of eXeLearning software, a postest similar to the initial test was applied to verify the progress against the concepts related to inorganic chemical functions, the results of the final test are shown in Figure 2.

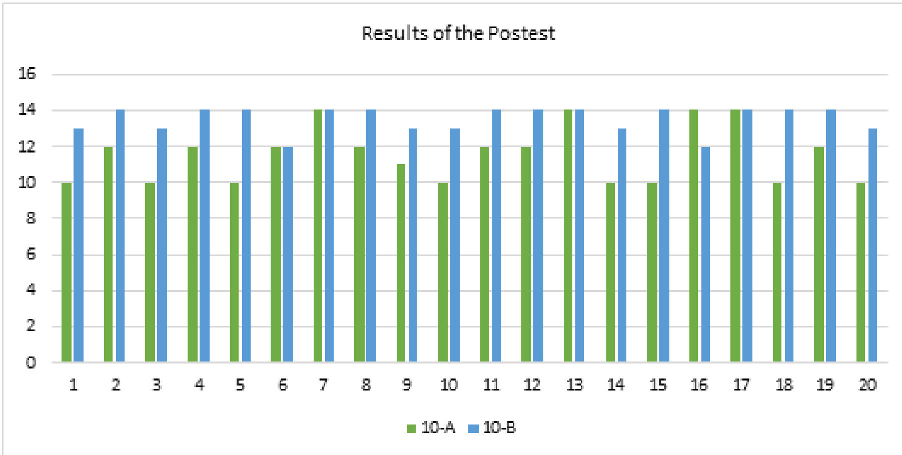

Figure 2: Correct postest answers for the control and experimental groups. Source: Author's Own Work.

Finally, the learning gain analysis is carried out using the Hake Factor (Bravo *et al.*, 2016; Fiad & Galarza, 2015). For this process, the correct answers of the pretest and posttest were taken into account both for the control group and for the experimental group. Equation 1 was used for this calculation.

$$g = \frac{postest(\%) - pretest(\%)}{100 - pretest(\%)}. \tag{1}$$

The following ranges are used to identify learning gain:

Low: g $\leq$ 0.3
Medium: 0.3 $<$ g $\leq$ 0.7
High: g $>$ 0.7

Hake Factor - Control Group:

$$g = \frac{77\% - 49\%}{100\% - 49\%} = \frac{28\%}{51\%} = 0.55 \tag{2}$$

Based on the results for the control group, it was possible to identify that the learning gain was **medium**, since the result was approximately 0.55. This group consisted of a total of 20 students.

Hake Factor - Experimental Group:

$$g = \frac{91 - 51}{100 - 51} = \frac{40}{49} = 0.82 \tag{3}$$

Table 1: Statistics of matched samples. Source: Author's Own Work. Software SPSS Version 22

	Variables	Mean	N	Standard deviation	Mean standard error
Par 1	Pretest 10 A	7,4000	20	1,95744	,43770
	Pretest 10 B	7,6500	20	2,43386	,54423
Par 2	Postest 10 A	11,5500	20	1,53811	,34393
	Postest 10 B	13,5000	20	,68825	,15390

Based on the results for the experimental group it was possible to identify that the learning gain was high since the result was 0.8. This group consisted of a total of 20 students. In addition, the averages of the results for both groups are analyzed to verify the variation that occurs in the groups before and after the pedagogical intervention using eXeLearning software. Table 1 shows the results of the descriptive statistics.

The design of the resources and activities for the teaching of inorganic chemical functions are presented in Figures 3, 4 and 5. There are shown some of the contents that were worked with the students through the implementation of the software.

Figure 3: Home in eXeLearning software for teaching inorganic chemical functions. Source: Author's Own Work.

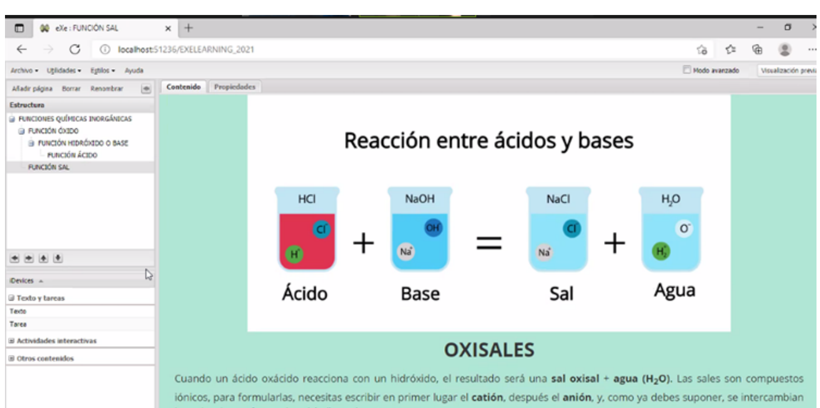

Figure 4: Space designed for teaching the chemical function of oxides. Source: Author's Own Work.

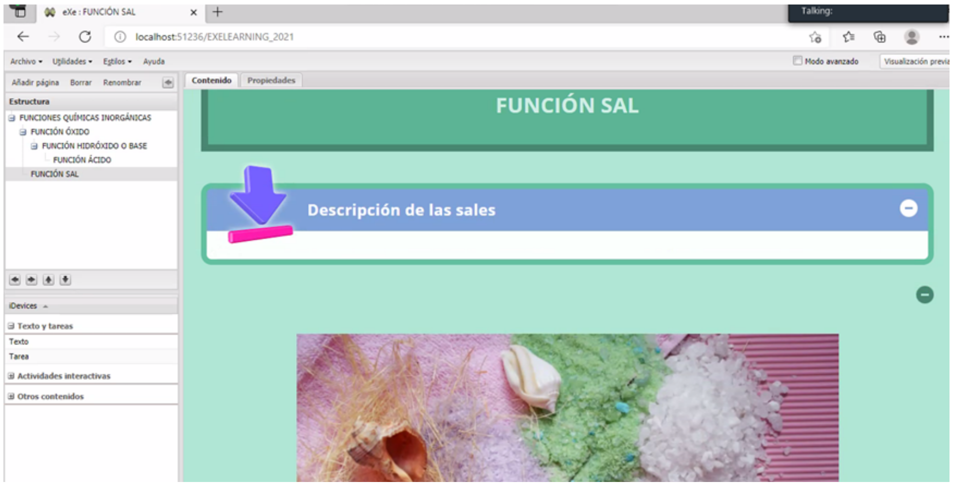

Figure 5: Space designed for teaching chemical function salts. Source: Author's Own Work.

4. DISCUSSION OF RESULTS

The emergence of COVID-19 triggered a paradigm shift in the daily social processes of individuals, significantly impacting various sectors, with education being one of the most profoundly affected. Education, a domain inherently shaped by societal evolution, has been intricately woven with the fabric of technology and its adaptive tools designed for educational contexts (Giraldo-Gómez *et al.*, 2019).

Amidst the challenges posed by the pandemic, Information and Communication Technologies (ICTs) played a pivotal role in enabling educators worldwide to sustain their training processes without disruption (Tinoco-Giraldo & Zuluaga Giraldo, 2019).

Furthermore, ICTs facilitated human connectivity even in the era of social distancing, giving rise to platforms and software that flourished due to their capacity to support communication while maintaining a commitment to quality education (Salazar *et al.*, 2011).

Within this context, the eXeLearning software emerged as a noteworthy alternative for educators. It offers the ability to design interactive spaces wherein students can engage remotely and access diverse resources and strategies, such as educational videos, infographics, blogs, reading materials, and assessment tools, thereby enriching the learning experience (Gallego *et al.*, 2016; Bernal-Jiménez & Rodríguez-Ibarra, 2019).

In the specific case of inorganic chemical functions, teachers designed and programmed various spaces to comprehensively cover the wide array of concepts associated with oxides, acids, bases, and salts.

An analysis of pretest results revealed that students possessed conceptual foundations in inorganic chemical functions due to the earlier inclusion of chemistry in the curriculum since the eighth grade. This prior exposure laid the groundwork for a more in-depth study in the tenth grade.

Comparing the standard deviations of pretest results for the control and experimental groups (1.95 and 2.43, respectively), it became apparent that variations existed between correct and incorrect responses. However, following the implementation of the eXeLearning-based educational strategy for the experimental group, a substantial decrease in standard deviation to 0.68 indicated an improvement in correct answers, signifying progress in learning inorganic chemical functions through the software (Gallego *et al.*, 2016).

Validation using the Hake factor for learning gain yielded a value of 0.5 for the control group (mean gain) and 0.8 for the experimental group (high gain). This suggests that the use of eXeLearning significantly enhanced the learning outcomes of the subject matter, underlining its effectiveness as an instructional tool (Salazar *et al.*, 2011). These results underscore the transformative potential of technology in education, particularly in adapting to and overcoming challenges posed by unprecedented circumstances such as the COVID-19 pandemic.

In line with this, recent studies show that the use of digital resources has a positive impact on learning inorganic chemistry. This is the case of eXeLearning and various digital tools which have been shown to improve students' motivation and performance in chemistry class (Jumbo-Jumbo & Gutiérrez, 2023; Largo-Taborda & Hurtado-Vinasco, 2024).

For example, studies such as those by Largo-Taborda *et al.* (2023) and Sosa *et al.* (2020) show that mobile applications and virtual simulators promote student participation and the understanding of subject-specific concepts which, in most cases, are complex for students.

In addition, virtual learning environments such as Moodle facilitate the design of activities and promote on the one hand the autonomy of students and enable collaborative work (Parra-Bernal & Agudelo-Marín, 2022). The use of software specialized in teaching chemistry, allows to mitigate the negative impact that has with the teaching of this subject considering that the topics covered are complex, need other areas to broaden their understanding and which in many cases do not articulate with the context and reality of the students (Largo-Taborda *et al.*, 2022a; Largo-Taborda *et al.*, 2022b).

As for limitations, the software requires for its construction internet access for the construction and design of the digital tool, however, the software has an off-version line which can be used in a variety of contexts where there is the possibility of using a computer. Each group had a sample of 20 students, the analyses showed that grade 10 A which was guided from master classes, obtained a learning gain of 0.5, which sets it in an average range, showing that classes given within the classroom, they generate learning in the students, but not very large, given the complex themes and the disinterest that the students present when studying for this case, inorganic chemical functions.

Grade 10 B had a learning gain of 0.8, placing it in the high range, showing that ICT-mediated strategies motivate students to learn subjects they consider complex, Generating in them a process of interest and motivation vis-à-vis inorganic chemical functions. Given that education is a learning process which is not only determined to the students' understanding of specific subjects, but also to the ability of those who guide them in this feat to have the tools and capacity for motivation towards the pupils, to make the understanding of subjects and learning as such more enjoyable and not part of an education within a traditional model, making it the educant himself who takes control of his process, which results in a more appropriate and less taxative education.

The use of a virtual software such as eXeLearning support what is mentioned in the previous paragraph, because the application of the different resources that compile it, they generated a greater willingness and interest in issues such as inorganic chemical functions, to which the eighth degree has a general approach that leaves as a conclusion that they are of high difficulty. The quantification of learning gains accounts for the moments when students manage to generate a process of understanding at the cognitive level of a given topic, the current situation of the pandemic in the face of covid-1919 contributed to a reinvention of classroom strategies as educational models.

Processes such as the investigation of knowledge generated from the pretest resulted in an academic diagnosis in the group with which we work, this allowed us to identify strengths and weaknesses and generate headings for feeding the software, in this way we tried to choose the subjects which were of greatest difficulty to point out in them and so, by carrying out again a test with the same characteristics, to assess and quantify whether this has been an educational strategy for the students, enabling them to overcome the constraints of inorganic chemical functions.

It was also shown that the eXeLearning interface is easy to use and its portability allows it to work without internet access, which not only generates an easy management of this multimedia resource in the teacher and student, if not, which further reduces the gap of inequality that arises in relation to education. The choice of a programme for teaching chemistry in this particular case should not only be easy to handle for the teacher, but he must also extrapolate his ideas concerning the programmers by thinking about the management and above all the access of his students to it.

By way of conclusion, the use of digital educational resources allows students to improve their interest and motivation for learning, in this particular case about inorganic chemistry and its chemical functions. On the other hand, it is imperative to consider that the use of digital tools such as eXeLearning, simulators, virtual practices, mobile devices and interactive platforms such as PhET (Santadaría, 2013),to mention some, always requires accompaniment, Planning and constant review to avoid interactions and failure to meet the proposed learning objectives.

5. CONCLUSIONS

The implementation of eXeLearning played a pivotal role in fostering a flexible and adaptable educational environment. This tool demonstrated its efficacy by offering portability, enabling its use without the necessity of internet access. This feature empowered teachers to tailor their instructional approaches according to the unique didactics inherent in each discipline, thereby facilitating the teaching of scientific concepts. Notably, eXeLearning proved instrumental in recognizing the centrality of science learning within curricular processes, aligning with the Ministry of National Education's (MEN) emphasis on elevating quality standards.

In addition to its portability, eXeLearning emerged as a catalyst for student engagement and motivation. The integration of interactive activities heightened students' interest, particularly in comprehending inorganic chemical functions such as oxides, acid hydroxides, and salts. This not only enriched the learning experience but also contributed to a more profound understanding of complex scientific concepts.

A crucial aspect underscored by the utilization of ICT tools, exemplified by eXeLearning, is the promotion of educational innovation. By incorporating these tools into teaching practices, educators gained the ability to transform their pedagogical approaches. This transformation extended to educational planning processes, where the inclusion of activities aimed at fostering meaningful and in-depth learning became a hallmark. The infusion of technology into the educational landscape thus not only modernized teaching methods but also paved the way for a more dynamic and effective learning experience for students.

Finally, considering the opportunities offered by eXeLearning allows teachers to adapt evaluation activities, concepts and processes based on various themes and areas of knowledge. On the other hand, it can be implemented in its online and offline version which provides an alternative to use it in various educational contexts. In addition, the use of digital resources promotes participation, collaborative learning, motivation and interest in learning from a playful and dynamic perspective.

Declaration of conflicts of interest

The authors declare that they have no conflict of interest related to this scientific article.

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Authors' contributions

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