Teacher scaffolding for knowledge building in the educational research classroom

Andamiaje docente para la construcción del conocimiento en el aula de investigación educativa

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ABSTRACT

Knowledge Building is an educational model characterized by its emphasis on the collective responsibility of students to improve collective ideas. Previous studies have demonstrated the benefits of Knowledge Building in science education. This study implements this pedagogy in the field of educational research and pursues two objectives: i) to analyze the quality level of student contributions when participating in a collaborative space to enhance ideas, and ii) to analyze the scaffolding employed by teachers during the implementation. A mixed-method design (qualitative and quantitative) was employed to collect data. The participants consisted of 59 undergraduate social education students enrolled in an action-research course. Data on the quality of discourse were collected from the entries or notes created by students on the Knowledge Forum platform, while data on teacher scaffolding as perceived by the students was obtained through interviews. The results of this study demonstrate that most student contributions are of high quality, although participation shows a slightly uneven distribution. Furthermore, this study broadens our understanding of the teaching scaffolds that support students' knowledge construction in educational research and offers teaching scaffolds that can be applied in various constructivist learning contexts aimed at promoting student autonomy to collaborate in knowledge creation.

Keywords: teaching; educational innovation; educational research; group learning; educational technology; didactic use of computer.

RESUMEN

La Construcción del Conocimiento es un modelo educativo que se caracteriza por su énfasis en la responsabilidad colectiva de los estudiantes para mejorar las ideas colectivas. Estudios previos han demostrado los beneficios de la Construcción del Conocimiento en la enseñanza de las ciencias. Este estudio implementa esta pedagogía en el campo de la investigación educativa y persigue dos objetivos: i) analizar la calidad de las contribuciones de los estudiantes al participar en un entorno colaborativo para mejorar las ideas, y ii) examinar los andamios utilizados por los docentes durante la implementación. Se utilizó un diseño de investigación mixta que incluyó enfoques cualitativos y cuantitativos para recopilar datos. Los participantes fueron 59 estudiantes del grado de educación social inscritos en un curso de investigación-acción. Los datos sobre la calidad del discurso se recopilaron a partir de las entradas o notas elaboradas por los estudiantes en la plataforma Foro del Conocimiento, mientras que los datos sobre los andamios docentes, tal como los percibieron los estudiantes, se obtuvieron a través de entrevistas. Los resultados de este estudio revelan que la mayoría de las contribuciones del alumnado son de alta calidad, aunque se observa una distribución ligeramente desigual en la participación. Además, este estudio amplía nuestra comprensión de los andamios de enseñanza que respaldan la construcción del conocimiento del alumnado en materia de investigación educativa, y ofrece andamios docentes que pueden aplicarse en diversos contextos de aprendizaje constructivista que persigan fomentar la autonomía del alumnado para colaborar en la creación de conocimiento.

Palabras clave: enseñanza; innovación educativa; investigación educativa; aprendizaje en grupo; tecnología de la educación; aprendizaje asistido por ordenador.

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INTRODUCTION

Nowadays, Social Constructivism is widely recognized and accepted as an educational theory. Social constructivism emphasizes the social nature of cognition and advocates for creating communities of learners who collaborate to achieve better outcomes in their learning (McLeod, 2019). From a Social Constructivist perspective, the collaborative learning approach argues that knowledge is less an individual possession and more a collective good. This knowledge is constructed by members of a group through participation in shared activities, and the exchange of ideas and resources (Yang, Zhu et al., 2022). In other words, collaborative learning involves an active process in which learners construct their understanding by taking advantage of their interactions with their environment and with other learners (Stahl, 2020). This approach focuses on designing and implementing educational environments that promote meaningful interactions among students, facilitating the appropriation of the knowledge construction process in a collaborative and personal way (Rannikmäe et al., 2020).

In recent years, lines of educational research based on technological innovations have been developed in alignment with the socio-constructivist perspective (Fernández-Miranda et al., 2022; Palacios-Ortega et al., 2022). Computer-supported collaborative learning (CSCL) focuses on the design and implementation of technology to support collaborative learning by facilitating learning processes and the sharing or co-construction of knowledge (Chen et al., 2018; Radkowitsch et al., 2020). Within the field of CSCL, many educators actively strive to create effective educational environments that promote collaboration among students and facilitate the development of shared understandings on complex knowledge issues (Zhang et al., 2020). These environments are designed to encourage the exchange and discussion of ideas, providing tools that facilitate cognitive and social interaction with the aim of achieving a deeper level of understanding (Schnaubert & Vogel, 2022). Teachers who prioritize student autonomy in learning for problem-solving recognize that CSCL is suitable for achieving these goals (McKeown et al., 2017). In CSCL environments, students demonstrate higher levels of learning, make higher-quality decisions, complete more thorough tasks, engage more equitably in the learning process, and experience greater satisfaction compared to those following more traditional educational approaches (Järvelä et al., 2020). These learning environments capitalize on peer collaboration, supported by technological tools, to monitor, assess, and enhance both collective and individual knowledge (Stahl et al., 2006). Furthermore, it is widely acknowledged that social interactions and collaborative efforts play a crucial role in the learning process, influencing the overall quality of the achieved outcomes (e.g., Järvelä et al., 2023). Extensive empirical studies and meta-analyses have widely reported the positive effects of computer-supported collaborative learning on students' learning outcomes and processes (e.g., Chen et al., 2019).

The work of Scardamalia and Bereiter (1996) is pioneering in the field of CSCL. They introduced the educational model called “Knowledge Building”, which involves students in the collaborative advancement of knowledge. Research on Knowledge Building (KB) has seen a significant increase in recent years (Gutiérrez-Braojos et al., 2020), with a substantial emphasis on the design and development of technologies and educational scenarios that facilitate student communities in collaboratively constructing their knowledge and assuming responsibilities (Stahl & Hakkarainen, 2021). This study investigates the effects of Knowledge Building on novice students

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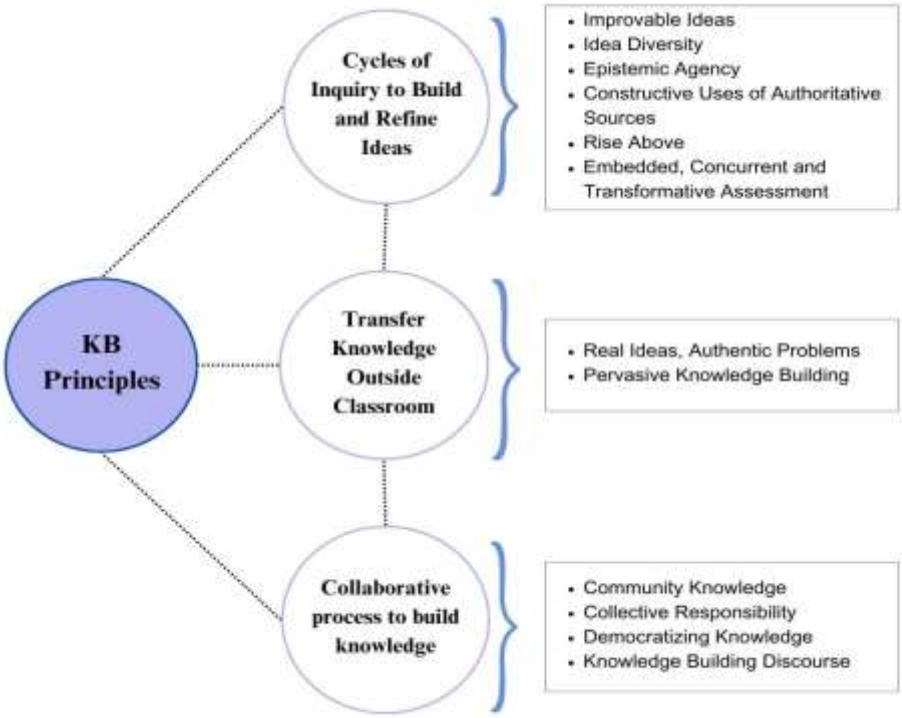
with limited knowledge of educational research. The subject of Educational Research presents a certain level of complexity. When students attempt to learn this subject, they often encounter comprehension difficulties (Gussen et al., 2023). There is evidence that an active and collaborative pedagogical proposal is efficient to teach science and research skills (Jiao et al., 2011; Vandiver & Walsh, 2010), but there are not so many studies carried out from the Knowledge Building pedagogy to teach research methods (Gutiérrez-Braojos et al., 2022). This study explores whether the socio-constructivist educational model Knowledge Building, based on collaboration among students to exchange and enhance collective ideas, fosters learning in the field of educational research.

An Educational Model for the 21st Century: Knowledge Building

In an era where information is readily accessible, Knowledge Building emerges as an educational model that fosters a culture of collaborative knowledge creation in educational environments (Scardamalia & Bereiter, 2021). Knowledge Building is inspired by Popper's theory of Objective Knowledge (Popper, 1972). This theory suggests considering three interconnected worlds to understand knowledge. 'World 1' is the physical world, 'World 2' is the realm of conscious experiences or subjective knowledge, and 'World 3' is the world of autonomous logical content products of the human intellect, such as that available in computers, libraries, etc. Knowledge Building is a model that transcends individual learning within 'World 2,' with the goal of enabling communities of learners to construct and refine shared knowledge in 'World 3,' much like communities and teams of scientists. It represents a promising educational model to developing students' competencies and skills needed to succeed in the 21st century (Tan et al., 2021). Knowledge Building has proven effective in empowering students, enabling them not only to acquire knowledge, but also to learn to collaboratively inquire, develop and refine ideas supported by reliable sources to solve real problems, and to take shared responsibility for cognoscitive advancement (Bereiter & Scardamalia, 2016).

Knowledge Building can be implemented across various educational contexts and disciplines[1], particularly in those related to the sciences. This is an educational model that effectively complements other educational innovations, such as in the field of robotics learning (e.g., Khanlari, 2019). The implementation of Knowledge Building in the classroom requires teachers to design an educational environment based on 12 principles (Scardamalia, 2002) (Figure 1). This environment facilitates opportunities for students to share, question, debate ideas, and develop new skills with the purpose of constructing and refining their knowledge about authentic problems (Ma & Scardamalia, 2022). This implies that teachers must progressively delegate responsibilities related to knowledge construction to students. To do this, teachers should provide various types of scaffolding to facilitate students during the Knowledge Building implementation. Scaffolding is a concept with its origins in sociocultural theory (Vygotsky, 1978). It refers to the process in which students have adaptive support tailored to their progress needs (Svendsen & Burner, 2023), while scaffolds are tools that provide support to complete a specific zone of proximal development (Puntambekar et al., 2021; Van de Pol et al., 2019).

Figure 1
Figure of the principles



In educational literature, there are various scaffolding proposals specifically designed to support students in meeting the challenges presented by a constructivist-based learning environment. For example, Finelli and Borrego (2020) suggest three ways to support students: planning the learning environment and conditions, identifying when students need explanations about the content or activities, and providing students with opportunities to achieve learning. Other proposals, such as that of Zhu and Lin (2023), focus on introducing scaffolding strategies to encourage students to collaborate in discussions and enhance their knowledge, such as: i) initiate an inquiry; ii) encourage students to elaborate on/deepen their ideas, iii) encourage students to build on ideas contributed by community members; iv) encourage new ideas or new inquiry directions; v) establish community norms; vi) direct instructions/guidance. In other words, teachers act as guides and mentors, providing guidance, feedback, as well as timely support, when necessary, to ensure that students engage and collaborate effectively to enhance their ideas.

Knowledge Forum: Technology for Collaborative Knowledge Building

Recognizing the significance of technological advancements to build knowledge (Popper´s three worlds), Knowledge Building has placed substantial emphasis on the educational innovation with technology (Khanlari et al., 2019; Tan et al., 2021). Knowledge Forum (KF) (Scardamalia, 2004) is a technological platform specifically designed to support Knowledge Building implementation in the classroom. This platform offers a structured environment that streamlines the development of crucial collaborative idea construction processes, including expressing ideas, building upon the contributions of others, critically evaluating information, and engaging in meaningful discussions (Laferrière & Lamon, 2010). Through its features, Knowledge Forum empowers participants to connect their ideas, explore diverse perspectives, and collectively foster a deeper comprehension of intricate concepts (Soliman et al., 2021).

Knowledge Forum offers a range of tools and functionalities that empower learners in their knowledge-building endeavors (see Figure 2). For instance, it allows students to generate and share their own contributions, nurturing a sense of ownership and agency in the learning process (Hong & Scardamalia, 2014). The platform also enables the organization and visualization of ideas, making it easier to organize their contributions (Bereiter & Scardamalia, 2016). Students using Knowledge Forum engage in online interactions employing various scaffolds to enhance collective knowledge, including posing questions, presenting proposals, offering explanations, and generating research (Gutiérrez-Braojos et al., 2018). Studies that have examined discourse through different categorization schemes have found that most students significantly contribute to the advancement and refinement of collective knowledge on the Knowledge Forum platform, while demonstrating a strong mastery of that knowledge (Cacciamani et al., 2021; Soliman et al., 2021; Yang, Zhu et al., 2022; Zheng et al., 2021).

Figure 2
Knowledge Forum Platform

The idea that students should assume that the responsibility for advancing knowledge is distributed among all members is a key pillar of Knowledge Building (Scardamalia, 2002). Knowledge Building is not an individual and isolated process but is enriched when the contributions and perspectives of all participants are valued and integrated. When students take on this shared responsibility, a sense of community and collaboration is fostered. In other words, students recognize that the responsibility for learning doesn't rest solely with the teacher or a handful of standout individuals. Instead, students understand that every member can provide a valuable contribution to the collective knowledge. This idea promotes equity and inclusion in learning, as it values the diversity of experiences, knowledge, and skills of all participants. In this line, Knowledge Forum provides opportunities for students to receive feedback from their peers and educators, fostering a culture of constructive criticism and continuous improvement (Tarchi et al., 2013). This dynamic is made possible thanks to the continuous improvements of the Knowledge Forum platform itself, as well as the creation of new technologies associated with Knowledge Forum, ensuring it remains at the forefront of educational technology. Some of these advancements are evident in the software's analytics capabilities, which provide teachers and students with tools for conducting concurrent and reflective assessments (Gutiérrez-Braojos et al., 2023; Teo & Tan, 2023, Yang, Zhu et al., 2022). Therefore, these technological innovations associated with Knowledge Forum facilitate a more responsive and insightful education.

The challenge of teaching in the subject of Educational Research

Higher education aims to train students who can address the complex challenges of contemporary society, overcoming limitations of thinking not supported by evidence (Murtonen & Salmento, 2019). Scientific reasoning and skills training are present, to a greater or lesser extent, in most education study programs worldwide (Gess et al., 2018). Pre-service educators should have a solid understanding of the discipline they are pursuing as professionals and engage in scientific inquiry to promote innovation in professional contexts (Ciraso-Calí et al., 2022). This will enable them to generate valuable knowledge and enhance their professional praxis. Scientific competence requires students to develop associated skills such as formulating questions, making conjectures, planning research, analyzing data, drawing conclusions, and practical implications (Bottcher & Thiel, 2018; Khan & Krell, 2019). However, recent studies claim that students who take courses in research methods often encounter many difficulties related to reasoning and scientific skills in the educational field, for example, collecting and analyzing data (Earley, 2014). In fact, students often perceive the research subject as uninteresting and irrelevant to their future careers, as well as challenging due to its difficulty (Nind et al., 2020). And therefore, students often show a passive or negative attitude towards learning educational research knowledge and skills (Gussen et al., 2023; Murtoten, 2015).

Schutt et al., (1984), (cited in Earley, 2014) recall the complexity associated with learning about research methods when they state that research is a "sustained task that involves a number of different kinds of activities that must be interrelated carefully and for which decisions made at one state of the process influence choices at later ones" (p. 242). In instances where the subject matter is particularly intricate, students may face challenges due to the intrinsic cognitive overload and lack of sufficient prior knowledge (Sweller et al., 2019) within the allocated time. Intrinsic load refers to the inherent complexity of a learning task, and this complexity is influenced by the interaction between the task elements and the student's prior knowledge (Liu et al., 2022). Element interactivity pertains to the combination of the number of elements to be learned and the number of interactions between each of these elements. The connection between intrinsic load and the student's prior knowledge lies in the fact that prior knowledge typically assists the students in reducing the interactivity of the elements (Endres et al., 2023). Moreover, there is a possibility that some students may become overwhelmed by the confusion, leading to frustration, and ultimately, complete disengagement from the learning process (Chevrier et al., 2019; Pekrun et al., 2014), making it necessary to provide additional guidance and support (Finelli & Borrego, 2020; Madison et al., 2022; Tharayil et al., 2018)

The current study

In this study, we conjecture that socioconstructivist educational approaches, which encourage students to share and refine their ideas and questions rather than keeping them to themselves, promote the improvement of knowledge at both the individual and collective levels (Stahl & Hakkarainen, 2021). Secondary studies have consistently shown positive outcomes in most of the Knowledge Building implementations, where students improve their collaborative skills and contribute to collective knowledge, while acquiring new knowledge (e.g., Chen & Hong, 2016). In fact, some of these effective implementations carried out through Knowledge Building have been in subjects related to reasoning and scientific skills (e.g. Gutiérrez-Braojos et al., 2022). In addition, there are very few studies that have explored teacher scaffolds to provide support to students while they improve and refine their ideas (Zhu & Lin, 2023).

In this study, we aim to assess the effectiveness of Knowledge Building in teaching all students in the field of educational research, as well as identify the teaching scaffolds perceived by students during the implementation of Knowledge Building. Specifically, this study aims to address the following research questions:

- (Q1) What are the overall effects and impacts of implementing Knowledge Building pedagogy in educational research?
    - (Q1.1) To what extent is the responsibility distributed among students to participate in a collaborative space to enhance collective knowledge?
    - (Q1.2) What levels of learning are reflected in individual contributions made by students in the Knowledge Forum?
    - (Q1.3) What student profiles are identified based on their contributions to the online platform?
- (Q2) What teaching scaffolds are positively perceived by learners in promoting collaboration among students and enhancing understanding of the subject?

METHODS AND MATERIAL

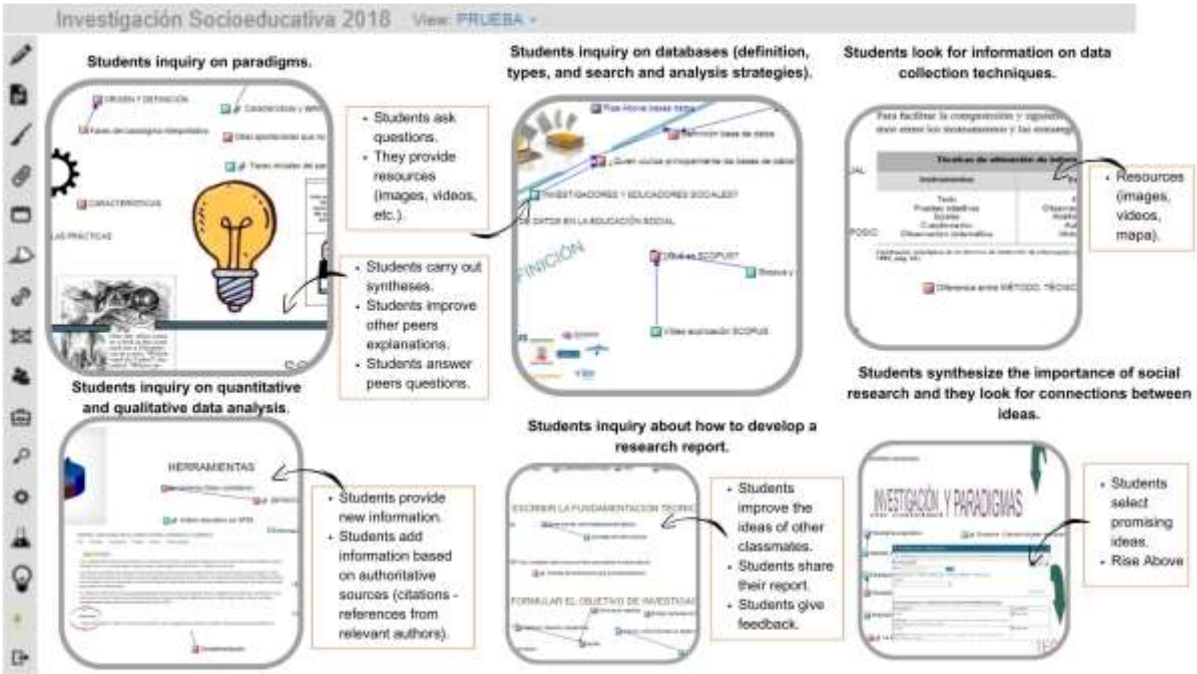
To address the research questions in this study, we employed a mixed-method design (Creswell & Guetterman, 2021). Johnson et al. (2007) refer to mixed methods research as that “in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., the use of and viewpoints on quantitative data collection, analysis, inference techniques) for the general purposes of breadth and depth, understanding, and corroboration" (p. 124). In this study, we addressed different threads to answer the questions posed, and with all of them, to understand the effects generated by the implementation of Knowledge Building, and the teaching scaffolds that support an effective implementation.

Participants and Course Environment

A total of 59 students were included in the sample of this study, all of whom were enrolled in a 16-week course focused on educational research where the Knowledge Building pedagogy was implemented. The course was facilitated through the Knowledge Forum platform (Figure 3). On average, participants dedicated approximately 3 hours per week to actively participating in the course activities in a hybrid environment, i.e., those environments in which "se difuminan las fronteras entre las actividades en línea y presenciales dando continuidad a los aprendizajes [the boundaries between online and face-to-face activities blur, providing continuity to learning]" (Coll et al., 2023, p. 11).

Figure 3

Moves to improve Knowledge about Educational Research Classroom



Students followed the work inquiry cycles described below to achieve the proposed knowledge objectives:

- Questions: students identify the questions they want to address and the aspects they would like to explore regarding a topic identified in the syllabus of the subject. These questions are distributed among small working groups.
- Information retrieval: students conduct thorough inquiry to answer the posed questions. They use both the materials provided by the instructor and different bibliographic databases to gather relevant data and academic sources.
- Individual and collective responses: the students develop their responses individually or collectively, then share and discuss their findings on the Knowledge Forum. This digital platform is designed to facilitate remote communication, collaboration, and the constructive work of ideas. Moreover, the platform records all the ideas generated by the community during the knowledge building process.

- Idea presentation: in class, students present the ideas registered on the Knowledge Forum platform, generating a debate around them. This exchange fosters reflection and collective and individual knowledge building, delving deeper into the topics addressed and generating new insights.
- Evaluation session: both the instructor and the students participate in an evaluation session. The teacher provides an assessment of the work in the Knowledge Forum, identifies possible errors, and suggests improvements.
- Formulating new questions: based on the feedback and reflections arising during the process, new questions are formulated to guide the subsequent phase of inquiry and knowledge building.

At the end of the course, students worked in small groups and selected valuable ideas related to the discussed topics. These were captured into concise texts and visual representations, which served the purpose of organizing and connecting ideas to foster a holistic understanding. These summarized representations enable quick access to key concepts of the course and promote deep understanding, connections between ideas, and effective communication of knowledge among course participants.

Data collection and analysis procedures

The data obtained from the Knowledge Forum records have been analyzed using Rstudio through four phases:

Firstly, an analysis of the registered participation in the Knowledge Forum platform was conducted. To assess the level of participation, the number of notes created by each student was quantified, and the GINI index was calculated. Gini coefficient, the Lorenz Curve, and derivative indices have been used in previous Knowledge Building studies (e.g., Gutiérrez-Braojos et al., 2018; Gutiérrez-Braojos et al., 2022), computer-supported collaborative learning (e.g., Chen et al., 2024; Slof et al., 2020; Strauß & Rummel, 2021; Tucker et al., 2020), and also in centimetric studies to analyze the equitable distribution of authorship (e.g. Salgado-Orellana et al., 2021), and collaboration in science (e.g., Rousseau et al., 2023). Additionally, a Lorenz curve was plotted to show the cumulative percentage of grades corresponding to the cumulative percentage of students in the community, accompanied by a descriptive polar graph of each student's participation.

Secondly, a content analysis of the contributions made by students in the Knowledge Forum was conducted using the SOLO taxonomy (initial coding phase matching 89%, authors reached complete agreement). The categorization system based on the Structure of the Observed Learning Outcome (SOLO) taxonomy (Biggs, 2011) was used in previous Knowledge Building (e.g., Chan et al., 2002; Schrire, 2006; Tammeleht, 2022, Gutiérrez-Braojos et al., 2022) and CSCL studies (e.g., Cai & Gu, 2022). SOLO taxonomy provides a structured framework with five levels of complexity, categorized into two levels, the surface level, and the deep level (Lister et al., 2006):

- The surface level includes pre-structural, unistructural, and multistructural contributions, which provide relevant elements but may be disconnected or disorganized:

  - Pre-structural level: This is the least sophisticated type of response; irrelevant elements are used, and necessary elements are omitted.
  - Unistructural level: This response reflects a partial understanding of the problem, with some aspects correctly understood but others still missing.
  - Multistructural level: This is a response where the student demonstrates comprehension of relevant components of the problem but is not aware of the interrelationships among them.

- The deep level includes relational level and/or extended abstract level:

  - Relational level: The student organizes the different components of the problem into a structure and uses that structure to successfully solve the question.
  - Extended abstract level: This is the most sophisticated type of response. Student's response surpasses the immediate question and establishes connections between the problem and a wider context.

Other contributions made for different reasons (e.g., community functioning, expressing gratitude, etc.) were omitted from this study. In the initial coding phase, the data were encoded by two authors with previous experience in the SOLO taxonomy (adding a third party in case of disagreement). This analytical strategy has been used in other studies as well (e.g., Holmes, 2005; Schrire, 2006). Subsequently, a descriptive analysis was conducted, and two graphs were created: a box plot illustrating the mean, median, and distribution of grades, and a polar graph showing the number of surface and deep grades for each student.

In the third phase, learners' profiles were analyzed according to their contributions on the online platform. Since the polar graphs seemed to indicate two groups of students, a robust cluster analysis using the K-medoids algorithm with PAM (which is not affected by outliers) was performed, resulting in two student clusters. Finally, significant differences between these clusters were tested, and effect sizes were calculated.

In the fourth phase, a content analysis of interviews with 10 graduate students was carried out. The purpose of this analysis was to identify the scaffolds that were implemented by the teachers and were perceived positively by students to promote collaboration among students and improve their understanding of the subject. Students were selected according to their level of achievement in the course to ensure the collection of a broader range of perspectives (3 students with a low level, 4 students with medium levels, and 3 students with a high level). The students participated in an extensive interview about their experience on the course. However, in this study, we only present the results of the questions used to collect data related to the scaffolding provided by the teachers: How was your learning experience in Knowledge Building? Have you faced any challenges or difficulties when collaborating with your peers to improve collective knowledge? What factors have helped you the most in collaborating with your peers to enhance collective knowledge? Have you noticed any teacher-provided assistance that is valuable for the community? The coding scheme proposed is based on the proposal of Finelli and Borrego (2020), Tharayil et al. (2018) and Zhu and Lin (2023) about scaffolds teaching to promote active learning. The data have been jointly coded by 2 authors. They separately analyzed the text to identify segments in which certain conditions occurred under which teachers provided support according to the students. Later, they coded and categorized these conditions according to the following categories and reached complete agreement.

- The category "Planning" corresponds to the teacher's scaffolds for preparing the implementation of KB in the subject.

    - Support to establish knowledge directions and trajectory: the teacher and students build together (teacher and whole class) a map of big questions/goals considering prior knowledge and what is expected in the subject.
    - Support students by providing authoritative sources: the teacher provides specialized literature to prevent students from feeling lost to afford questions.
    - Supporting students by providing technologies for collaborative work: the teacher provides the Knowledge Forum tool, which is in line with the principles of Knowledge Building.
    - Support students by providing a sequence of inquiry: the teacher establishes heuristic to improve collective ideas (i.e., cycle of steps to inquiry and advancement of knowledge).

- The category 'Explanation' refers to the introduction, clarification, and description of issues related to cognitive difficulties that arise during the knowledge building process.

    - Support students in understanding what is expected from them in KB pedagogy: the teacher assists students who have difficulties to understand what is expected to fulfill with KB principles.
    - Support students in understanding how to use KF platform: the teacher assists students who have difficulties using certain tools in the Knowledge Forum.
    - Support students to write notes on KF according to science criteria: the teacher explains and provides examples of what constitutes a well-written note versus a poorly written one in the KF (take time to look information and reflect about it, clarity, conciseness, evidence-based, and the use of keywords; look for evidence to corroborate or counter-argue a peer's idea; take time to write and revise a note, including citation and references).
    - Support students to do good discourses moves to build on issues shared on community according to KB principles: the teacher explains and provides examples of how to contribute and refine collective knowledge (for example, elaborating analogies to explain ideas, looking for new perspectives, carrying out synthesis of their ideas), and what discourse moves are not appropriated (for example, repeating peers' ideas).
    - Supporting students who require additional assistance to understand complex concepts for them: the teacher identifies misconceptions or encounters difficulties in understanding complex concepts during discussions within larger groups or by requesting feedback from students about epistemic emotions (e.g., confusion) The teacher explains why students are confused about these issues, suggests actions to clarify doubts, or asks questions to facilitate deeper understanding.

- The category "Facilitation" refers to teaching scaffolds aimed at ensuring student engagement throughout the implementation of the goals until their completion.
    - Provides opportunities and encourages students to stay updated on shared ideas on the platform: the teacher allocates time and motivates students to critically read their peers' contributions and select promising ideas.
    - Provides opportunities and encourages students to take ideas from the Knowledge Forum and expand upon them: the teacher provides time and motivates students to correct or improve their peers' ideas or propose new ones.
    - Provides opportunities and encourages students to challenge themselves with knowledge: the teacher poses challenging questions to enhance platform ideas/perceptions.
    - Provides opportunities and encourages students to participate in the platform/class discussion: when participation is improvable (either collectively or individually), the teacher informs about the current state of participation, encourages, and allocates time for students to participate in the Knowledge Forum or in-person discussions each week.
    - Provides opportunities and encourages students to become more autonomous working with platform ideas: the teacher motivates students to take initiative in the community (reducing teacher support as the course progresses).
    - Provides opportunities and encourages students to maintain a democratic environment in the community: the teacher encourages students to respect democratic norms when participating in online discussions or class (taking turns to speak, tolerance for other opinions or diversity of ideas, helping others when requested, etc.).

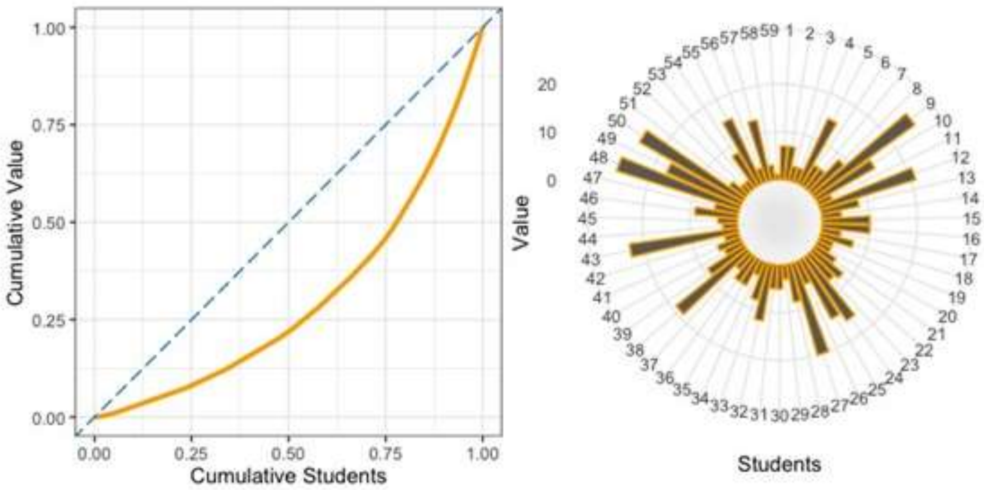
RESULTS

Result 1: Equidistribution of participation

The students made a total of 506 individual contributions ($\overline{x}$=8.58, Sd=6.64), of which 5.14% were classified as "community functioning" and the rest as "contributions to the improving of community knowledge". The Gini coefficient value (G = .39) indicates a slight inequality in the distribution of grades among the students.

The Lorenz curve graph shows clear leadership in terms of participation, as 75% of the students have made slightly less than 50% of the contributions, while the remaining 25% account for the rest. These same results can be observed in the polar graph (Figure 4), where each bar represents the contributions of a student.

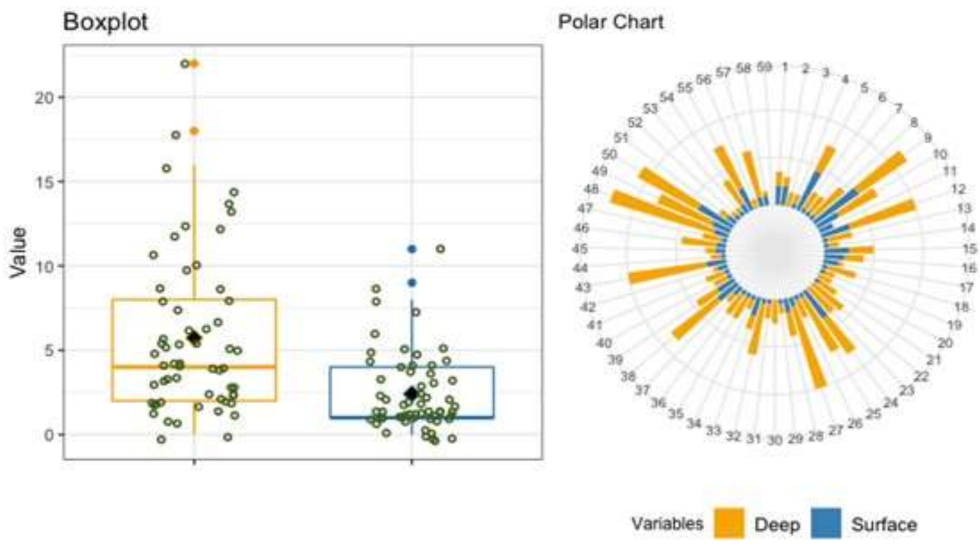
Figure 4
Community leadership based on participation in the online platform



Result 2: Level of learning reflected in the individual contributions

Figure 5 shows the results of the contribution quality analysis. It reveals that students produced a higher number of notes categorized as deep level (n=338; $\overline{x}$=5.73, Sd=4.78) compared to superficial level (n=142; $\overline{x}$=2.41, Sd=2.33). Furthermore, the results reveal types of participation (Figure 5). In other words, a few students predominantly created surface notes (e.g., S2), while others focused on producing deep notes (e.g., S27). However, there are also students who consistently contributed both surface and deep notes about educational research issues (e.g., see S9).

Figure 5
Deep Vs. Surface Notes

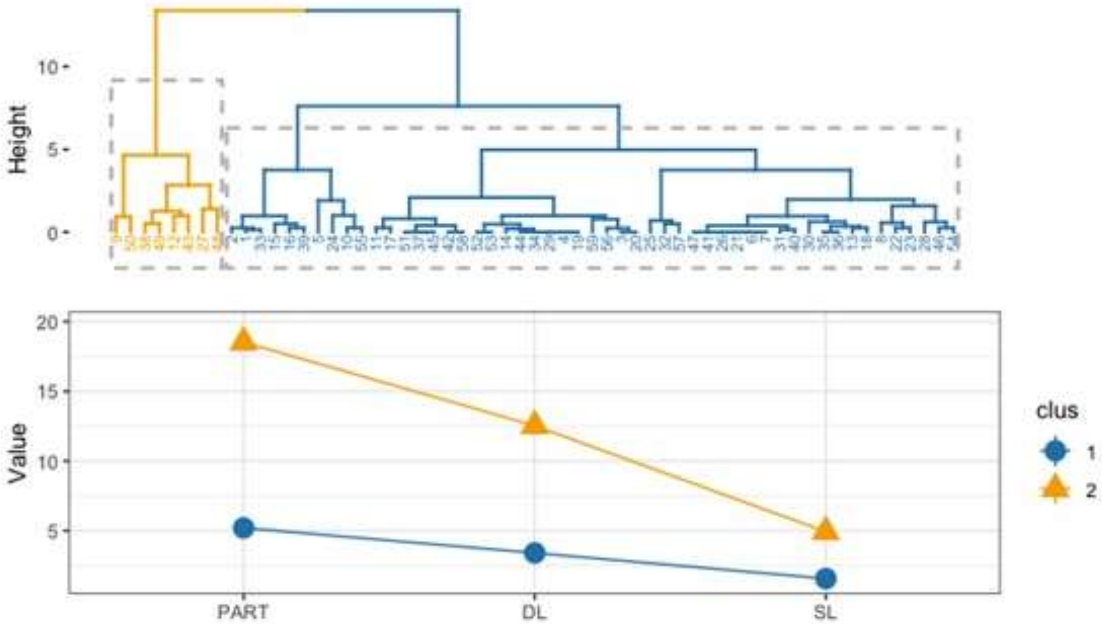


Result 3: Students´ patterns

To explore potential student profiles, a robust K-Medoids clustering algorithm was applied using the PAM method (Figure 6). To determine the optimal number of clusters, we employed two methods: the Gap Statistic and Silhouette. Both methods indicated an optimal number of 2 clusters. Cluster "C1" consists of 44 students ($\bar{x}_{Participation}$=5.2, $Sd_{Participation}$=2.38; $\bar{x}_{Deep}$=3.41, Sd_{Deep}=2.03; $\bar{x}_{Surface}$=1.57, $Sd_{Surface}$=1.3). Cluster "C2" comprises 15 students ($\bar{x}_{Participation}$=18.53, $Sd_{Participation}$=5.07; $\bar{x}_{Deep}$=12.52, Sd_{Deep}=3.96; $\bar{x}_{Surface}$=4.93, $Sd_{Surface}$=303).

Although both clusters include students who produce more deep notes than superficial ones, they show significant differences between each other in the three variables ($z_{Participation}$=-5.31, p-$value_{Participation}$<.001; z_{Deep}=5.02, p-$value_{Deep}$<.001; $z_{Surface}$=-4.58; p-$value_{Surface}$<.001). Moreover, they exhibit large effect sizes ($z_{Participation}$=.75; z_{Deep}=.74; $z_{Surface}$=.55). Interestingly, both clusters exhibit similar results in terms of the number of superficial notes. Additionally, cluster "C2", composed of leading students, even showed slightly more superficial notes than cluster "C1". Although the leadership cluster is mainly characterized by greater participation and a higher number of deep notes.

Figure 6
Cluster Dendrogram: 2 types of student's patterns

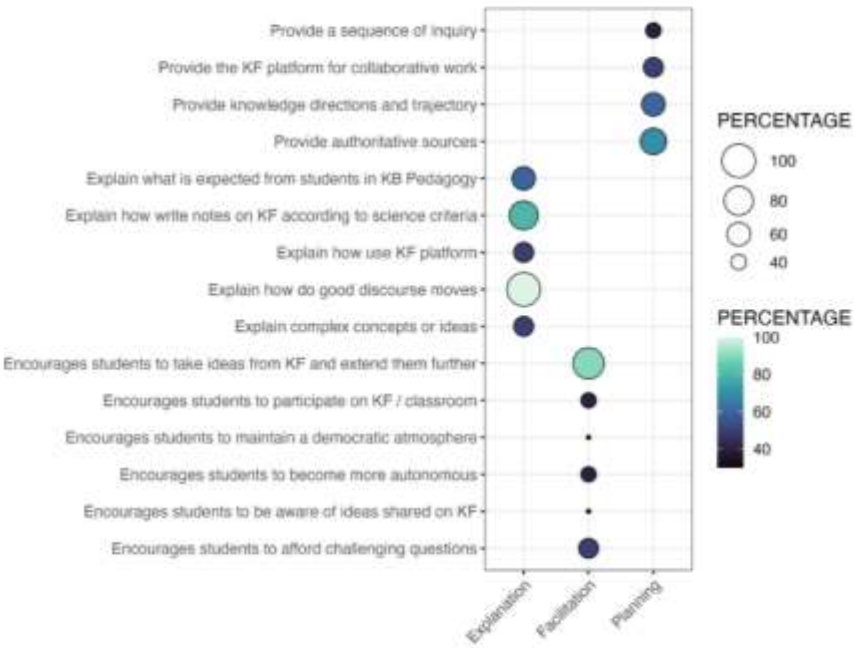


Result 4: Teaching scaffolds perceived by learners

Teaching scaffolds were organized into three types: planning, explanation, and facilitation (Figure 7). Qualitative evidence indicates that the students greatly appreciate collaborative planning scaffolds, where both they and the teacher actively participate in defining learning goals within the educational community. At the beginning of the course, the teacher plans with the students a map of the major questions they will investigate. The students affirm the importance of being part of the planning to feel ownership and responsibility for their own learning process. The students express that knowing what was expected of them and the purpose of their tasks helped them relate the activity to their learning and professional practice. On the other hand, the students state that the use of a flexible work sequence to guide the students' actions was a very effective scaffold. Additionally, the students highlight the access to different resources and materials provided by the teacher. Regarding explanatory scaffolds, especially at the beginning of the subject, it was crucial for the students to receive specific instructions on how to provide quality notes. Furthermore, the students emphasize the importance of the explanations for the proper use of the Knowledge Forum platform in accordance with the principles of Knowledge Building. This is because, initially, the students stated that for them, participating in the Knowledge Forum meant delivering a task on time, regardless of repeating the ideas that their peers had developed on the platform. However, with the explanations and examples from the teacher, they understood that participation in Knowledge Building means improving the ideas previously shared by their peers on the platform. Also, over time they began to appreciate the importance of basing their ideas on authoritative sources. Lastly, the students highlight creating advanced syntheses of previous notes as a very useful practice to encourage their participation. As for the facilitation scaffolds, the students express that the teacher posed (cognitively) challenging questions that generated greater commitment when delving into the collective ideas shared on the platform. Moreover, they appreciate that the teacher promoted diversity of ideas, continuously inviting them throughout the course to read the contributions of others, provide feedback, and ask questions to deepen their knowledge. Thus, the incremental efforts of the students, under the guidance of the teacher, were key in overcoming the initial difficulties. This means that the contributions and feedback from the teacher were important in overcoming the initial difficulties and guided the participation of the students throughout the course.

A percentage analysis was carried out to determine the most popular teaching scaffolds among students. According to the results obtained, students appreciated three types of teaching scaffolds during the implementation of KB pedagogy (Figure 7). A first type of scaffolding aims to provide a framework for collaborating on the improvement of ideas (e.g., KF, sequence of inquiry and other sources), and the shared goals of knowledge (creating a collaborative map of significant questions). Some of these scaffolds aim to help some students understand what is expected of them and how they can achieve it. Students need the teacher to explain what is expected of their participation in Knowledge Building pedagogy (i.e., questioning the content of other previous collective ideas, connecting various collective ideas, avoiding repetition of previous collective ideas, and improving upon previous collective ideas). They also value guidance on the quality standards they should meet (i.e., writing notes supported by evidence, clear and concise writing, citing, and referencing, etc.). Some of them also appreciate assistance in understanding how to use the Knowledge Forum platform correctly (i.e., appropriate use of the Knowledge Forum) and how to work in collaborative inquiry cycles to enhance their knowledge in research methods (i.e., working sequence). Likewise, students may already possess certain skills, but they require the teacher to provide them with a challenge and motivate them to confront it (i.e., encouraging to be more autonomous), or simply motivate them to do something (i.e., be aware of peers ‘ideas reading notes on KF).

Figure 7
Teaching scaffolds to foster knowledge building



DISCUSSION AND CONCLUSIONS

In this study, the Knowledge Building model was implemented, an established educational model recognized for its significant impact in the field of Computer-Supported Collaborative Learning (CSCL). The purpose was to train students in the field of educational research. To evaluate the benefits of Knowledge Building, we have analyzed student participation on the Knowledge Forum platform.

Firstly, we analyzed the distribution of student participation in the Knowledge Forum by calculating the Gini coefficient (this coefficient provides objective information on how participation was distributed among members). The Gini coefficient results reveal a slight inequality in participation in the Knowledge Forum. This indicates that many students show a similar level of commitment, but some students were more active participants than their peers, and leadership roles were concentrated within a subset of students. While a perfect distribution of participation may not be feasible or ideal in practice, we can assert that there are certain thresholds of inequality that indicate some students delegate the responsibility to contribute to the community to their peers (Gutiérrez-Braojos et al., 2018). Therefore, in future studies, it would be advisable to use scaffolds that promote the rotation of leadership among students when teaching (see Ma et al., 2019).

Secondly, we analyzed the level of knowledge reflected in the students' contributions in the Knowledge Forum using the SOLO taxonomy. The results show that most contributions were of high quality. Some students provided greater consistency in contributing in-depth notes, while others offered a combination of in-depth or high-quality, and superficial or low-quality contributions. Furthermore, a deeper analysis was conducted to identify student profiles based on their contributions, leading to interesting findings. The results reveal that the cluster with more active or participatory students also shows a higher proportional constant regarding the relationship between in-depth and superficial notes. In other words, both clusters produce superficial notes, but highly participatory students not only have more notes in total but also tend to maintain a higher proportion of in-depth notes compared to superficial ones (see Cacciamani et al., 2021; Yang, Yuan et al., 2022). The variability in the quality of the notes prepared by students in the Knowledge Forum, regardless of cluster affiliation, could be explained by the complexity of the educational research topic (Gussen et al., 2023). This could indicate the need to implement evaluative technologies that help students monitor, recognize their difficulties, reflect, and seek timely support from peers, the teacher, or any other resource. Similarly, the teacher could use these evaluative technologies to identify students who require help understanding concepts that may be especially complex for them.

Thirdly, the results reveal that students valued a variety of teaching scaffolds consistent with previous findings (Zhu & Lin, 2023). Some of these scaffolds are related to establishing a set of objectives or meta-questions for the course from the start, as well as providing a heuristic or inquiry sequence to collaboratively address these issues. These results are aligned with the literature on learning regulation (Järvelä et al., 2023). For students to intentionally engage in the learning process and consequently regulate their behavior and thinking toward achievement, it is essential that they are aware of the objectives (and criteria) to be achieved in the course, as well as those steps that increase the chances of success (Van de Pol et al., 2019). Other teaching scaffolds that stood out are explaining and motivating students to take concrete actions in challenging moments to improve collective knowledge (e.g., see Bereiter & Scardamalia, 2016). This leads us to conclude that students may lack sufficient skills to collaborate effectively in knowledge construction, underscoring the relevance of educational models like Knowledge Building in today's education. Students also emphasized the importance of the teacher's explanations on specific topics (e.g., complex concepts). This supports research indicating that addressing the content of the educational research topic poses a cognitive challenge for students related to their knowledge background (e.g., Sweller et al., 2019) and the crucial motivational and intellectual support of teachers (Madison et al., 2022; Nind et al., 2020).

In summary, the implementation of Knowledge Building has positive effects on learning outcomes and the quality of discourse among participants, even though students may have different profiles. The results of this study, although improvable, demonstrate that students are capable of collectively constructing knowledge (Scardamalia & Bereiter, 2021). Previous studies have shown that in a classroom where Knowledge Buildind is implemented, all ideas are valued and contribute to progressive discourse (e.g., Tan et al., 2021). This inclusion benefits both high-achieving students and those with lower performance (e.g., Yang, Yuan et al., 2022). Collaborative work between these groups of students helps to advance knowledge through questions, explanations, additional materials, etc. For this, we have identified that teaching scaffolds play a crucial role in enhancing constructive participation in online discourse for all students in Knowledge Building environments (Zhu & Lin, 2023). This study contributes to our understanding of the specific ways in which teaching scaffolds support students in Knowledge Building. Likewise, this study provides strategies that can be used in other collaborative constructivist learning contexts.

Future research could investigate the effects that the use of Generative Artificial Intelligence (GAI), such as ChatGPT (García Peñalvo et al., 2024), could have on the quality of progressive student discourse (e.g., Tan et al., 2023), without negatively interfering with student learning. Some of the teaching scaffolds pointed out in this study could be covered with the use of ChatGPT. For example, reviewing and identifying improvements in the drafting of a note, synthesizing different ideas, or looking for analogies to an idea to facilitate its understanding. In addition, we suggest that future studies could focus on deepening the understanding and development of technologies associated with facilitating reflective assessments and encouraging participation. These technologies could take advantage of these findings about teaching scaffolds that are appreciated by students (Teo & Tan, 2023).

Finally, a limitation of this study is the sample size. Although the observed trends provide a useful preliminary view, the generalization of the results to a broader population is limited. A larger sample could offer a stronger and more diverse representation of the target population, allowing a more detailed analysis of variations within the sample. Therefore, understanding the effort involved in carrying out these applied research studies, we recommend that future studies coordinate efforts to expand the sample to overcome these limitations. Future research avenues also include conducting systematic reviews of Knowledge Building-based interventions.

NOTES

1. You can access resources on the implementation of KB and KF across various disciplines and educational levels: https://ikit.org/kbi/index.php/knowledge-building-resources/

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CRediT

Author 1: Actively participates in each role of CrediT (conceptualization, data curation, quantitative and qualitative formal analysis, funding acquisition, investigation, methodology, project administration, resources, software-programming-analysis, supervision, validation, visualization, writing original draft, writing-review editing, APA style, translation, review that this text is an original paper). Author 2: Actively participates in some roles of CrediT (data curation, qualitative formal analysis, collaborating with investigation, validation, collaborating with visualization, collaborating with writing-review editing, APA style, collaborate with the translation). Author 3: Actively participates in some roles of CrediT (collaboration with Data curation-validation-support as the third analyst, review that this text is an original paper). Author 4: Actively participates in some roles of CrediT (collaboration with Data curation-support as the third analyst and collaborate with APA style).

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