Bridging Bilingual Teacher Preparation to Professional Development in Science and Engineering Education

Conectando la formación bilingüe con el desarrollo profesional en ciencia e ingeniería

Conectando a formação bilíngue ao desenvolvimento profissional em ciência e engenharia

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Abstract

This paper investigates the transformative potential of a collaborative group of bilingual preservice and inservice teachers who co-designed and implemented a new science and engineering summer program for elementary and middle grades students. By centering culturally and linguistically sustaining pedagogies within professional development, we explore how foundational insights from preservice teacher preparation—specifically in science, engineering, and translanguaging—can meaningfully inform and strengthen inservice teaching strategies throughout the academic year. The study highlights the value of engaging bilingual educators in iterative cycles of reflective practice, emphasizing how collaborative professional learning communities can foster sustainable and equitable teaching practices. We examine how teacher teams utilized students' cultural and linguistic assets as a cornerstone of curriculum design and instructional delivery, bridging theory with practical classroom application. Drawing on both empirical classroom examples and relevant theoretical frameworks, this research outlines a professional development model that is responsive, asset-based, and teacher-driven. The model builds on the knowledge and enthusiasm cultivated during preservice training while addressing the dynamic, real-world challenges encountered by educators in increasingly diverse educational settings. Ultimately, our goal is to offer actionable strategies for bridging the persistent gap between preservice preparation and inservice professional growth, thereby supporting more effective, culturally relevant science and engineering instruction, and promoting teacher leadership and collaboration.

Keywords:
preservice, inservice, professional development, culturally sustaining, science, engineering, education.

Resumen

Este artículo investiga el potencial transformador de un grupo colaborativo de docentes bilingües en formación inicial y en servicio que codiseñaron e implementaron un nuevo programa de verano de ciencia e ingeniería para estudiantes de primaria y secundaria. Al centrar las pedagogías cultural y lingüísticamente sostenibles dentro del desarrollo profesional, exploramos cómo los conocimientos adquiridos en la preparación docente inicial —específicamente en ciencia, ingeniería y translenguaje— pueden informar y fortalecer significativamente las estrategias de enseñanza en servicio a lo largo del año escolar. El estudio resalta el valor de involucrar a educadores bilingües en ciclos iterativos de práctica reflexiva, enfatizando cómo las comunidades de aprendizaje profesional colaborativas pueden fomentar prácticas de enseñanza sostenibles y equitativas. Examinamos cómo los equipos docentes utilizaron los recursos culturales y lingüísticos de los estudiantes como base para el diseño curricular y la entrega instruccional, vinculando la teoría con la aplicación práctica en el aula. A partir de ejemplos empíricos y marcos teóricos relevantes, esta investigación presenta un modelo de desarrollo profesional receptivo, basado en activos y dirigido por los docentes. El modelo se construye sobre el conocimiento y entusiasmo cultivado durante la formación inicial, abordando al mismo tiempo los desafíos dinámicos del contexto educativo actual. Nuestro objetivo es ofrecer estrategias prácticas para cerrar la brecha entre la formación docente inicial y el crecimiento profesional continuo.

Palabras clave:
formación inicial, en servicio, desarrollo profesional, culturalmente sostenible, ciencia, ingeniería, educación.

Resumo

Este artigo investiga o potencial transformador de um grupo colaborativo de professores bilíngues em formação inicial e em exercício que cocriaram e implementaram um novo programa de verão de ciência e engenharia para alunos do ensino fundamental e médio. Ao centrar as pedagogias cultural e linguisticamente sustentáveis no desenvolvimento profissional, exploramos como os conhecimentos adquiridos na formação inicial de professores —especificamente em ciência, engenharia e translanguaging— podem informar e fortalecer significativamente as estratégias de ensino em exercício durante o ano letivo. O estudo destaca o valor de envolver educadores bilíngues em ciclos iterativos de prática reflexiva, enfatizando como comunidades colaborativas de aprendizagem profissional podem promover práticas pedagógicas sustentáveis e equitativas. Examinamos como as equipes docentes utilizaram os recursos culturais e linguísticos dos alunos como base para o planejamento curricular e a prática pedagógica, conectando teoria e aplicação prática em sala de aula. A partir de exemplos empíricos e de referenciais teóricos relevantes, esta pesquisa apresenta um modelo de desenvolvimento profissional receptivo, centrado em ativos e orientado pelos próprios professores. O modelo se baseia no conhecimento e entusiasmo cultivado durante a formação inicial, ao mesmo tempo que aborda os desafios dinâmicos enfrentados por educadores em contextos diversos. Nosso objetivo é oferecer estratégias práticas para superar a lacuna entre a formação docente inicial e o desenvolvimento profissional contínuo.

Palavras-chave: formação inicial, em exercício, desenvolvimento profissional, culturalmente sustentável, ciência, engenharia, educação.

Introduction

Bilingualism has established a significant presence in numerous teacher preparation programs across the United States, reflecting a growing recognition of the nation's linguistic diversity and the need for educators equipped to serve multilingual learners. These programs often offer specialized coursework, endorsements, or even full degree programs in bilingual education, focusing on areas such as dual-language instruction, second language acquisition theories, culturally responsive pedagogy, and assessment of bilingual students. This established presence ensures that many graduating teachers enter the profession with foundational knowledge and skills to effectively support bilingual students and create inclusive classrooms that value linguistic diversity.

However, in states like Georgia, where this study takes place, the integration of bilingualism into teacher preparation programs is still in a developmental phase. This affects key curricular areas, particularly preservice teacher training and inservice professional development. Consequently, many teachers in Georgia may lack the specific training and resources needed to effectively implement bilingual or multilingual approaches in their classrooms, as the teacher training programs do not require them to develop these skills. This gap can hinder the creation of truly multilingual learning environments that leverage students' full linguistic repertoires and support both content learning and language development. Addressing this disparity requires focused efforts on developing and implementing robust bilingual education coursework within teacher preparation programs and providing ongoing professional development opportunities for practicing teachers.

In this study, supported by the National Science Foundation (Award #2121351), we also focus on training preservice teachers to teach science and engineering in elementary and middle grades education, following the Science Georgia Standards of Excellence, which are adapted from the Next Generation Science Standards (NGSS, 2012). Preservice teacher training in areas like science—often relegated to second-place status—or emergent areas like engineering education, which is still developing in many Georgia school districts, is essential to improving science and engineering literacy in the classroom. This study was implemented in a summer program where preservice teachers implemented lesson plans under the guidance of university faculty and three inservice teachers. Then, after participating in the summer program, preservice teachers were asked to implement similar lesson plans during the school year in their schools of placement.

Theoretical Framework

In this paper, we describe how translanguaging is intertwined with the science and engineering methodology to teach a group of elementary and middle grades students in a summer program. On the one hand, our approach was grounded in translanguaging, a culturally and linguistically sustaining pedagogy that has been defined as a tool that allows emergent bilingual students to use all their available semiotic resources to make meaning (García & Wei, 2014). Buxton et al. (2021) emphasized that it empowers students to fully utilize their linguistic repertoire, embracing the richness and diversity of their home languages rather than suppressing them to conform to dominant social and political norms. This approach fosters inclusivity, validates their cultural identities, and challenges systems that ignore, marginalize, or devalue non-standard language practices —especially in states that are newly engaging with multilingualism in the classroom (Cardozo-Gaibisso et al., 2024). By creating a learning environment that respects and integrates these linguistic assets, students can engage more authentically and meaningfully, enhancing their overall educational experience.

On the other hand, the summer program's content was guided by science and engineering methodologies, aligning with the Science Georgia Standards of Excellence. The science methodology follows a structured five-step process: engage, explore, explain, elaborate, and evaluate (Bybee, 2015), ensuring a comprehensive approach to understanding scientific concepts. In contrast, the engineering methodology builds on these steps with additional processes that address its unique focus on problem solving and innovation. The steps are: **ask**, where students familiarize themselves with the context and the problem; **research**, where students use resources to find out how others have approached the problem; **imagine and plan**, where students brainstorm ideas, discuss the benefits and disadvantages of possible solutions, and begin planning how to build a prototype; **create and explain**, where students build the prototype and the teacher addresses the concepts that will be used to explain the prototype's performance; **test**, where students use the prototype and gather data about how it solves the problem or how it can be improved; **improve**, where students make changes to the prototype; and **communicate results**, where students use science concepts to prepare materials that explain their data and the prototype's performance. This iterative process emphasizes creativity and practical application. Together, these frameworks provided a robust set of pedagogical tools for fostering critical thinking and hands-on learning in the program.

Methodology

The purpose of this exploratory research is to understand how preservice teachers use translanguaging to teach science and engineering in a flexible environment such as a summer program with the guidance of inservice teachers and university faculty. All ethical considerations were taken into account in this IRB-approved study, and informed consent was obtained from the participants. In terms of participants, preservice teachers participating in this summer program are entering their junior and senior years after they conclude their participation in the summer program. In the following, we will focus on the preservice teachers entering their senior year as seniors experience more intensive work in the classroom that includes implementation of lesson plans with the guidance of a mentor teacher in the school of placement. There was a total of 11 preservice teachers entering the senior year in the fall semester, three of whom were in the elementary and eight of whom in the middle grades programs. These preservice teachers collaborated with peers to develop, implement, and assess lesson plans and classroom activities under the supervision of mentor teachers. While they had prior experience in general lesson planning, they were still developing their skills in planning for science, engineering, and translanguaging. Three of the rising senior preservice teachers were fully bilingual in English and Spanish, while the others reported experiences such as taking Spanish classes or practicing conversational Spanish in countries where the language is spoken. The in-service teachers participating in the summer program as mentor teachers were experienced educators, each with more than 10 years of teaching in public schools and working with emergent bilingual students. These in-service teachers served as mentors and supervisors during the summer but did not fulfill that role during the fall semester.

The data used for this paper were collected at different moments: the initial preservice teacher application to the summer program, the development and implementation of the science and engineering activities, the exit survey in the summer, and six online meetings and classroom observations during the school year. We use thematic analysis as a qualitative approach to study the data from the summer and fall semesters by systematically coding the sources, identifying recurring patterns and themes, and interpreting how these themes reflect the experiences, perceptions, and growth of the preservice teachers. This process allows us to explore their initial expectations, their engagement and learning during the program, and their reflections on its impact, providing a comprehensive understanding of the program's effectiveness and areas for improvement. At the same time, we examine how mentor teachers in the fall semester supported preservice teachers in developing and implementing science and engineering activities, and how they used translanguaging in the process.

Context

The Science Methods courses for elementary and middle grades preservice teachers, along with the Summer Scholars STEM Institute, were hosted at the University of North Georgia (UNG) Gainesville campus. These programs aimed to provide preservice teachers with hands-on experience in designing and implementing STEM lessons, while offering rising 4th–8th grade students an engaging summer learning experience in science and engineering.

Preservice Teacher Recruitment and Course Structure

Preservice teachers were recruited during the February –March period through targeted outreach to education students interested in science instruction. The program officially commenced in the third week of May and spanned 12 instructional days. During this period, preservice teachers attended the Science Methods course from 9:00 a.m. to 12:30 p.m., Monday to Friday, under the guidance of three university faculty members and two inservice teachers. The course was designed to enhance their pedagogical skills in STEM education and translanguaging, culminating in the development of one science lesson plan and one engineering lesson plan. The structure of the course allowed for collaborative lesson planning, peer review, and iterative refinement to ensure high-quality, student-centered instructional materials.

Summer Scholars STEM Institute

Following the completion of their lesson plans, preservice teachers had the opportunity to implement their instructional designs during the Summer Scholars STEM Institute for 15 days. This program welcomed 82 students who had just concluded their school year and were preparing to transition to their next grade level in August. These students, designated as rising 4th–8th graders, participated in the Institute from 9:00 a.m. to 3:00 p.m., Monday to Thursday. Each day at the Summer Scholars STEM Institute was carefully structured to provide a balanced and immersive STEM experience. During the morning session, students engaged in hands-on science activities designed by the preservice teachers. These activities focused on inquiry-based learning, fostering critical thinking, and applying scientific concepts through experiments and interactive discussions. After the lunch break, students transitioned to engineering-focused activities, which emphasized problem-solving, design thinking, and the application of engineering principles. They worked on team-based projects, exploring real-world engineering challenges and constructing prototypes. Recess, the final hour of the day, provided students with a recreational break, where they had access to outdoor play areas and the campus gymnasium.

Working in Schools during the School Year

During their senior year, preservice teachers collaborated with mentor teachers in regular classrooms throughout the fall and spring semesters. These placements spanned multiple school districts across the five university campuses. In this study, preservice teachers were assigned to four schools within two districts, where multilingual student populations were significantly represented. However, the extent to which multiple languages were integrated into instruction varied across schools. Their experiences were shaped by several key factors, including the school's instructional culture, the amount of time allocated to science education, and the attitudes of inservice teachers and principals toward the use of different languages in the classroom. The following sections will explore these aspects in greater detail.

Results

First, we describe the findings related to preservice teachers' work during the summer, followed by their implementation of activities during the school year. It is important to note that during the summer portion, preservice teachers implemented their activities with the support of university faculty and inservice teachers, who were flexible in how the activities were carried out in the classroom—particularly regarding the time needed to complete them. Implementing activities during the school year, on the other hand, proved more difficult due to the lack of scheduling flexibility, as preservice teachers had to adapt to the limited time allocated to science, which was significantly reduced compared to subjects such as language arts or math.

Translanguaging, Science and Engineering Instruction (Summer)

The sources reveal that creating a welcoming and effective learning environment for multilingual learners involves several key strategies. Teachers in the program emphasized the importance of allowing students to use their native languages in the classroom. This included permitting students to write and speak in Spanish, providing translations, and making resources available in multiple languages. For example, one preservice teacher noted:

> "It was really cool to use Spanish because I know that in my [experience], it's not that it was discouraged [...] but students didn't get translated worksheets, and they didn't have the closed captions feature in presentations [...] I just feel like it made the kids who do prefer to speak it a lot more welcomed in the classroom [...] and that's honestly something I would like to implement within my classroom."

This preservice teacher also shared that she created hard copies of a Kahoot quiz with Spanish translations for students who needed them. Another teacher noted that students were more likely to express themselves fully in writing when allowed to use Spanish. Additionally, teachers learned to incorporate technology to support multilingual learners, such as using live Spanish subtitles on presentations and videos. They also used visual aids and *realia* to clarify concepts. This approach involved being flexible and adaptable—for example, printing out PowerPoint slides for students with vision challenges.

An elementary preservice teacher explained:

> "So, I definitely know how to better differentiate for students who speak multiple languages and who come from different cultures. As for me, we were provided with a lot of resources on that, and I found out about a lot of apps that I can use to integrate into the classroom—like how to put captions in another language on my presentations and such."

Furthermore, teachers found that understanding the reasons behind student behavioral was critical for effective instruction of multilingual learners. They learned that behavior issues often stemmed from a lack of comprehension of the material or instructions —not from a lack of effort. This realization led teachers to actively seek out ways to meet the needs of students struggling with the language barrier instead of assuming a lack of attention or interest. These strategies included translating instructions, providing additional support, and creating an emotionally safe environment. Teachers also understood the importance of valuing students' cultural backgrounds and incorporating their interests into lessons. During an exit interview, a preservice teacher shared that collaborating with inservice teachers helped her to support students by "tak[ing] advantage of a second language" during classroom instruction. They did this by getting to know their students on a personal level by asking them about their families, favorite foods, and what they like to do for fun. They also incorporated these things into lesson planning. They recognized that understanding each student's unique cultural and linguistic background was an important part of creating a supportive learning environment.

The program provided teachers with valuable experience in implementing science lessons. Many teachers found the 5E model (Engage, Explore, Explain, Elaborate, Evaluate) to be a useful framework. They learned the importance of using hands-on activities and experiments to engage students and deepen their understanding of scientific concepts. For example, one group of teachers facilitated a sound and vibration activity in which students used a wave generator to measure the frequency of sound waves. Another group had students build their own cardboard cities to explore the principles of magnetism, using a paperclip car and a magnet placed beneath the model city to move it. These hands-on approaches helped students make connections between abstract scientific principles and real-world applications.

The teachers also recognized that students needed to use scientific terms to explain their thinking and understanding. In addition, they realized the importance of modeling scientific inquiry and encouraging students to ask questions and investigate further.

Teachers also found the need to be flexible and adaptable, often adjusting their lesson plans based on the resources available and student needs. They learned to use a variety of resources such as the National Science Teacher Association (NSTA) resources, and to collaborate with their colleagues to prepare engaging and effective science lessons. They incorporated the use of technology, like having translated subtitles for presentations and videos. Teachers also found that connecting lessons to students' interests and cultures was important for creating relevant and engaging learning opportunities. For example, one group incorporated a genetics activity using dragons to model heredity. Teachers learned to create a supportive classroom environment where students felt comfortable asking questions—even if that meant having to explain something multiple times.

One middle grades preservice teacher noted: "We noticed that most of our students needed to work on just expressing. They know, they know the topic, the material, but it's just—write it down, express it."

This insight shaped how they designed their lesson plans and activities, aiming to provide opportunities for students to express themselves in meaningful ways.

The sources also demonstrate that the teachers gained significant experience in implementing engineering lessons. They learned to follow the engineering design process, which often involved students working together to solve problems using creativity and critical thinking. One group of teachers had students work on a project that involved designing a cardboard city and using magnets to move toy cars through it. Many teachers believed that these types of hands-on, student-centered projects helped develop students' problem-solving skills and encouraged them to be more creative. The engineering lessons also provided opportunities to integrate science concepts and show how they can be applied in real-world scenarios. Teachers used activities that helped students understand complex ideas—such as heredity—in fun and engaging ways.

Teachers recognized that engineering lessons should be structured, yet allow for student-led exploration and discovery. They incorporated the use of models and demonstrations, as well as real-world applications. While most found the engineering design process useful, some felt that the steps were too numerous for the time allotted. Similar to their approach to science, teachers understood that it was important to connect engineering lessons to students' interests. They learned to use a variety of resources and to adjust their lessons as needed. Teachers also recognized that implementing engineering lessons required flexibility and thoughtful planning. They saw the need to design activities that allowed students to work at their own pace and collaborate in different group configurations.

Preservice Teachers' Work During the School Year

In this second context, as mentioned above, preservice teachers experienced a more rigid environment when trying to implement science and engineering activities using translanguaging. Inservice teachers who served as mentor teachers during the school year were not especially familiar with either the translanguaging or the engineering methodology. With science, many were familiar with the methodology but did not use all the five steps when implementing the activities. This impacted how preservice teachers used the skills learned during the summer.

The use of multiple languages during the school day varied across classrooms and schools. In three schools, principals actively encouraged multilingual instruction for certain students, as their student populations were proficient in multiple languages. From these three schools, one had a long-established culture in which teachers consistently integrated both English and Spanish into instruction across all content areas. In the second school, an emerging bilingual approach was being developed, with students placed in different classrooms based on their language use and proficiency. However, the overarching goal in this school was for students to transition to English-only instruction. In the first and second schools, mentor teachers provided explicit support to preservice teachers in utilizing different languages for instruction, offering guidance on strategies and best practices. At the third school, preservice teachers independently implemented translanguaging, as the mentor teacher did not provide specific guidance on its use. However, the mentor teacher did not restrict the practice of translanguaging by either the students or the preservice teachers within the classroom.

For the rest of the schools, the use of translanguaging was reduced, discouraged, and, in some cases, not allowed during instruction time. This limited how preservice teachers developed their activities, connected with students, and fostered a welcoming learning environment in the classroom. Preservice teachers noted that inservice or mentor teachers often did not know how to use multiple languages during instruction; and in other cases, the principal discouraged it.

Preservice teachers had more positive experiences planning and implementing science activities when following the structured science methodology used in the summer program, compared to using translanguaging and implementing engineering activities. Inservice teachers, who served as mentors, were already familiar with the five-step approach and, in most cases, allowed preservice teachers to implement most of the steps. Throughout these experiences, preservice teachers received mentorship and supervision during both the planning and execution of lessons, which enhanced their learning process. This support was especially valuable in classrooms where translanguaging was incorporated, as it allowed for more inclusive and dynamic instruction that engaged multilingual learners more effectively.

One of the biggest challenges preservice teachers faced was the limited time allocated for science instruction compared to subjects like language arts and math. The amount of time available for science varied across schools, with some scheduling science only once a week—typically on Fridays— while others operated on a rotating schedule every other week. In one case, a preservice teacher struggled because the school's instructional culture did not align with the 5E methodology. Instead of engaging in hands-on learning, students were restricted to reading text passages about science topics, missing the opportunity to explore concepts through experimentation and inquiry-based activities.

Among the three methodologies, engineering was the most challenging to implement during the school year. Preservice teachers faced several obstacles in planning and executing engineering activities, with the most common issue being the significant amount of instructional time required. Engineering projects often involve an iterative process where students design, build, and test a prototype, then refine their designs to improve performance. This process demands time not only for constructing and testing but also for making connections between the prototype's performance and underlying science concepts. However, many schools allocate limited time for hands-on learning, making it difficult to fully engage students in the engineering design cycle. Elementary and middle school students need sufficient time to gather materials, learn how to use tools, and analyze evidence to explain how their creations addressed a problem and the challenges they encountered throughout the process.

Another major challenge was the lack of familiarity with engineering instruction among inservice teachers. Since many were not familiar with the engineering design process, they were unable to provide preservice teachers with meaningful feedback during lesson planning and implementation. Without experienced guidance, preservice teachers often struggled to structure activities effectively or anticipate potential student difficulties. As a result, engineering lessons were sometimes incomplete or lacked the depth necessary for students to fully grasp the problem-solving aspects of engineering.

Conclusion

The findings from this study highlight the significant impact of the summer program on preservice teachers' ability to design and implement STEM instruction, particularly in science and engineering. During the summer, preservice teachers benefited from flexible scheduling, mentorship from university faculty and inservice teachers, and the opportunity to engage in translanguaging practices to support multilingual learners. This environment allowed them to explore student-centered methodologies, including the 5E science model and the engineering design process, in ways that fostered creativity, critical thinking, and deeper student engagement. However, when transitioning to the school year, preservice teachers encountered various constraints, including limited instructional time for science and engineering, a lack of familiarity with translanguaging among inservice teachers, and inconsistent support for hands-on learning across different schools. These barriers often restricted their ability to fully implement the strategies they had practiced over the summer.

Despite these challenges, the experiences gained through the summer program provided preservice teachers with a strong foundation in STEM education and translanguaging instruction. The structured science methodology was the most successfully implemented during the school year, as it was already familiar to many inservice teachers. Nonetheless, implementation was still constrained by limited time for science instruction and, in some districts, the use of scripted curricula for inservice teachers. limited time for science instruction and, depending on the school district, the scripted curriculum for inservice teachers. Engineering instruction remained the most difficult to integrate due to time constraints and a lack of mentor support. Engineering requires more time, as students' prototypes oftentimes need to be improved and retested. This iterative process poses additional demands in terms of time and materials.

Similarly, translanguaging practices varied widely, with some schools embracing multilingual instruction while others discouraged or outright prohibited it. These findings underscore the need for continued professional development for inservice teachers, particularly in engineering education and multilingual instructional strategies, to create more supportive environments for both preservice teachers and their students. Strengthening these areas can enhance the implementation of STEM education and foster more inclusive learning experiences for diverse student populations.

Implications/Future Steps

Future steps will focus on expanding professional development opportunities for inservice teachers to enhance their familiarity with the engineering design process and translanguaging strategies, ensuring better support for preservice teachers during the school year. Schools should consider allocating more instructional time for STEM subjects, particularly engineering, to allow for hands-on, inquiry-based learning that fosters critical thinking and problem-solving skills. Additionally, fostering a school-wide or district-wide culture that values multilingual instruction contribute to create more inclusive learning environments for diverse student populations. We also plan to explore strategies for integrating engineering education into existing curricula without compromising time for other subjects and examine the long-term impact of translanguaging on student engagement and academic performance. In addition, we aim to connect science and engineering after-school programs with inservice teachers, preservice teachers, and university faculty to strengthen collaborative partnerships. These efforts can enhance university–K–8 school relationships, bridge gaps in instructional practices, and provide sustained mentorship for preservice teachers as they transition into full-time teaching roles.

Notes:

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Max Vazquez Dominguez: conceptualization, data curation, research, methodology design, administration, supervision, validation, visualization, writing of the draft and review of the manuscript.
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Romola Bernard: data curation, research, methodology design, administration, supervision, validation, writing of the draft and review of the manuscript.

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The dataset supporting the findings of this study is not publicly available.

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