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## Exploring the Use of AR in Teaching Grammar to ESL Students: A Mixed-Methods Study

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### ABSTRACT

**Background.** The rapid advancement of educational technology has opened new possibilities for integrating Augmented Reality (AR) into English language teaching, particularly in grammar instruction for ESL learners. Traditional grammar teaching often depends on abstract explanations and repetitive drills, which can reduce learner engagement and limit contextual understanding.

**Purpose.** This study aimed to examine the effectiveness of AR-based instruction in improving ESL students' grammatical competence and learning engagement compared to conventional grammar teaching methods. It also sought to explore learners' perceptions of AR as a tool for understanding abstract grammatical concepts.

**Method.** A mixed-method research design was employed involving 80 intermediate-level ESL learners divided into an experimental group receiving AR-based grammar instruction and a control group receiving traditional instruction. Quantitative data were collected through pre- and post-tests.

**Results.** The findings revealed a significant improvement in the experimental group's post-test grammar scores compared to the control group ( $p < 0.01$ ), indicating that AR-based instruction positively influenced grammatical mastery. Qualitative results showed that learners perceived AR as highly engaging, motivating, and effective in helping them visualize and understand abstract grammatical concepts.

**Conclusion.** By transforming abstract language forms into immersive and context-rich learning experiences, AR promotes deeper understanding, learner autonomy, and sustained motivation, demonstrating strong potential to redefine grammar teaching through student-centered and technology-enhanced approaches.

### KEYWORDS

Augmented Reality, Educational Technology, Grammar Instruction

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### INTRODUCTION

Grammar has long been considered the structural foundation of language, serving as the framework through which meaning is constructed and communicated (Hou & Keng, 2021). In English as a Second Language (ESL) contexts, grammar instruction plays a vital role in developing learners' linguistic competence and communicative accuracy (Pruitt, 2022). Traditional grammar teaching methods often emphasize rule memorization and repetitive drills, focusing on form rather than meaning. While such methods can help learners recognize grammatical patterns, they frequently fail to promote deep understanding or the ability to apply



grammar meaningfully in real communication (Lehikko & Nykänen, 2024).

Recent developments in educational technology have provided opportunities to transform grammar instruction into a more engaging and experiential process (Vonkova dkk., 2021). Augmented Reality (AR), a technology that overlays digital information onto the real world, has gained attention for its ability to create interactive learning environments (Zolfaghari dkk., 2025). Through AR, abstract grammatical concepts can be visualized in tangible ways, helping learners perceive linguistic structures in authentic contexts. This experiential approach aligns with constructivist learning theories, which posit that learners construct knowledge through interaction and engagement with their environment (Sa'ud dkk., 2023).

Studies in language education have shown that multimodal and immersive environments enhance learners' attention, motivation, and retention. AR-based instruction allows learners to manipulate linguistic elements, observe their syntactic relationships, and receive immediate feedback (Esfandiari & Mazharpour, 2025). Such features make grammar learning less mechanical and more meaningful. In ESL classrooms, where engagement and comprehension often pose challenges, AR represents an innovative solution to bridge cognitive and experiential learning (Bahari & Gholami, 2022).

Previous research in AR-assisted language learning has primarily focused on vocabulary acquisition, reading comprehension, and pronunciation improvement. These studies consistently report positive outcomes in learner motivation, interaction, and performance (Lena & Nikolov, 2025). However, grammar despite its centrality to language mastery has received limited attention in AR-based interventions. The relative complexity of grammar structures and the abstract nature of syntax have made it difficult to visualize using traditional teaching tools, highlighting a need for new pedagogical strategies (Hava, 2024).

Emerging empirical studies have begun to explore the use of AR in grammar instruction, showing promising but inconclusive results (Luo dkk., 2024). Some findings suggest that AR enhances learners' grasp of spatial and structural grammar patterns, while others report only short-term improvements. These mixed outcomes indicate that while AR holds potential for grammar learning, its effectiveness depends on design, context, and learner interaction (Katsarou dkk., 2023).

The broader pedagogical landscape also points to an increasing emphasis on technology-enhanced learning in ESL education. Teachers and institutions are seeking innovative ways to integrate technology without losing pedagogical integrity (Zeybek & Sayın, 2022). AR, when strategically embedded in language curricula, can complement communicative and task-based approaches, enabling learners to internalize grammar rules through visualization and contextualization. Understanding how AR contributes to grammar acquisition is therefore crucial for developing future-ready ESL pedagogies (Zhao, 2025).

Despite growing interest in AR-assisted learning, research specifically addressing its role in grammar teaching remains limited. Most studies in this area focus on general attitudes toward technology or on lexical and phonological aspects rather than syntactic comprehension (Bahari, 2022). The gap lies in understanding how AR can concretely support learners' mastery of grammar forms and their ability to transfer this understanding into communicative competence. Without empirical evidence, it is difficult to justify the integration of AR into formal grammar instruction on a larger scale (Belda-Medina & Goddard, 2024).

Limited studies that address grammar learning through AR often employ small samples or short intervention periods, resulting in inconclusive or context-specific findings. There is also a lack of mixed-method investigations that combine quantitative performance data with qualitative insights into learner experience (Liao dkk., 2024). This methodological gap prevents a holistic

understanding of how AR affects not only learning outcomes but also learner engagement, motivation, and cognitive processing (Hajmalek & Rabiee, 2023).

Another underexplored dimension concerns how learners of different proficiency levels interact with AR-based grammar content. It remains unclear whether AR benefits beginners more than advanced learners, or whether the novelty of technology merely produces temporary engagement effects (Qizi, 2025). The pedagogical mechanisms through which AR enhances grammar comprehension such as visualization, interactivity, and contextual immersion are not yet fully understood.

Existing ESL grammar instruction frameworks rarely integrate digital media in ways that foster both form-focused and meaning-focused learning (Sivakami & Gunasekaran, 2025). The absence of well-designed AR interventions hinders educators from aligning technological innovation with pedagogical soundness (Law, 2024). Therefore, systematic inquiry into the design, implementation, and evaluation of AR-supported grammar learning is necessary to bridge this theoretical and practical divide.

Exploring the integration of AR in grammar teaching is essential because it aligns with the evolving nature of 21st-century education, where multimodal and interactive learning environments dominate. Grammar, as one of the most abstract components of language learning, requires pedagogical innovation that transforms form-focused instruction into contextually meaningful experiences (Abad-Bataller & ..., 2025). AR provides a unique opportunity to make grammar visible, manipulable, and experientially engaging. This research seeks to investigate how AR can enhance grammatical understanding, learner motivation, and overall engagement in ESL classrooms (Marrahi-Gomez & Belda-Medina, 2024).

The study is guided by the rationale that meaningful learning emerges when cognitive engagement intersects with experiential interaction. By employing a mixed-method design, this research aims to capture both the measurable effects of AR on grammar accuracy and the subjective experiences that shape learner motivation and perception. Understanding these interrelations will allow educators to design more effective technology-based grammar instruction that goes beyond superficial engagement.

The hypothesis underlying this research posits that AR-supported grammar instruction can significantly improve ESL learners' grammatical accuracy and retention while fostering positive attitudes toward language learning. This study contributes to the field by developing an evidence-based framework for integrating AR into ESL grammar teaching. The findings are expected to advance both theoretical understanding and pedagogical practice in technology-enhanced language education, particularly within contexts striving for interactive, learner-centered instruction.

## RESEARCH METHODOLOGY

The study employed a mixed-methods sequential explanatory design to explore the effectiveness of Augmented Reality (AR) in teaching grammar to English as a Second Language (ESL) students (Hussanee dkk., 2024). The quantitative phase aimed to measure improvements in grammatical accuracy and retention, while the qualitative phase investigated learners' experiences, perceptions, and engagement with AR-based instruction. The integration of both approaches allowed for a comprehensive understanding of how AR affects both learning outcomes and learner attitudes. The research design followed Creswell and Plano Clark's framework, emphasizing the triangulation of statistical and narrative data to ensure validity and depth. Quantitative data provided measurable evidence of impact, whereas qualitative insights revealed underlying mechanisms influencing learners' motivation and comprehension (Purwanto dkk., 2025).

The population consisted of intermediate-level ESL learners enrolled in a language institute in Jakarta, Indonesia. Participants were selected based on their English proficiency and willingness to engage in technology-enhanced learning. The final sample included 80 students divided into two groups: 40 in the experimental group using AR-based grammar learning modules and 40 in the control group receiving traditional instruction. Stratified random sampling was applied to ensure balanced representation in terms of gender, age, and prior technology exposure. Additionally, five ESL teachers participated as facilitators and observers, providing feedback on classroom implementation and learner behavior. This diversity ensured that findings reflected both learner performance and pedagogical perspectives.

Three instruments were used to collect data: grammar proficiency tests, learner perception questionnaires, and semi-structured interview guides. The grammar tests, consisting of 40 items on syntax, verb forms, and sentence structure, were administered before and after the intervention to assess improvement. The questionnaire, designed on a five-point Likert scale, measured learners' motivation, engagement, and perceived usefulness of AR in grammar learning. The interview guide was developed to elicit in-depth qualitative insights regarding learners' experiences, challenges, and perceptions of AR interactivity. All instruments were validated by three experts in applied linguistics and educational technology. A pilot study involving 15 non-participating students yielded a Cronbach's alpha coefficient of 0.89, confirming high reliability and internal consistency across the measurement tools.

The study was conducted over an eight-week period divided into three phases: preparation, implementation, and evaluation. During the preparation phase, grammar modules were developed using AR-based applications such as BlippAR and Assemblr EDU, which enabled learners to visualize sentence components and manipulate grammatical structures in real time. Both groups received identical grammar topics, but the experimental group interacted with AR content, including 3D sentence models and contextual visualizations. Teachers underwent brief training sessions to ensure consistent facilitation of AR-based tasks.

During the implementation phase, the experimental group engaged in two 60-minute AR-assisted sessions per week, while the control group followed conventional lessons using printed exercises and whiteboard explanations. Immediate feedback was provided through the AR system, allowing learners to correct grammatical errors autonomously (Zhu dkk., 2024). The evaluation phase involved post-tests, survey distribution, and focus group interviews to capture both performance outcomes and learner reflections. Quantitative data were analyzed using paired-sample t-tests and ANCOVA to measure differences between groups, while qualitative data were coded thematically using NVivo software. The integration of both datasets provided a holistic analysis of how AR influenced grammatical comprehension, motivation, and learner engagement within ESL contexts (Dehghanzadeh dkk., 2021).

## RESULT AND DISCUSSION

The quantitative data consisted of grammar pre-test and post-test scores from 80 ESL learners divided equally between experimental and control groups. Table 1 presents the descriptive statistics for both groups. The experimental group, which utilized AR-based grammar learning, achieved a mean post-test score of 83.45 (SD = 5.22), compared to a pre-test mean of 67.80 (SD = 6.10). The control group, taught using traditional instruction, showed a smaller gain, with a post-test mean of 74.30 (SD = 6.87) from a pre-test mean of 68.40 (SD = 5.95).

**Table 1.** Descriptive statistics of grammar test scores

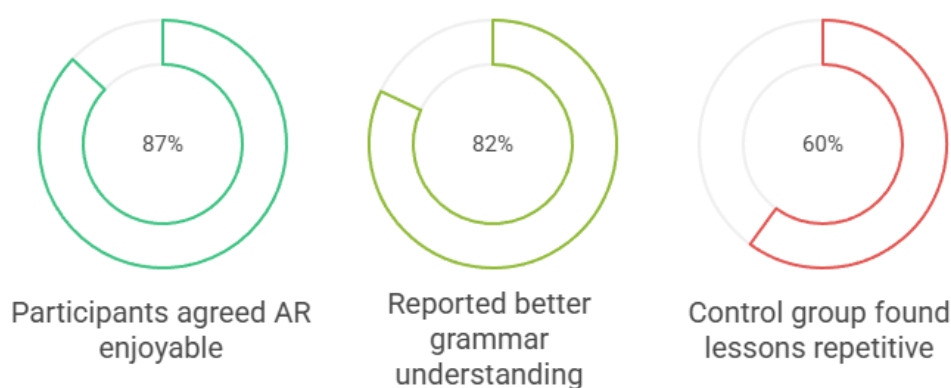
Group	N	Pre-Test Mean	SD	Post-Test Mean	SD	Mean Gain
Experimental (AR)	40	67.80	6.10	83.45	5.22	15.65
Control (Traditional)	40	68.40	5.95	74.30	6.87	5.90

The descriptive results demonstrate that both groups improved, but learners exposed to AR instruction exhibited significantly higher mean gains. The standard deviation of post-test scores for the AR group was lower, indicating more consistent performance improvement across participants. These findings suggest that AR may promote more uniform learning outcomes and reduce variability in grammatical mastery.

The improvement in grammar proficiency among the experimental group can be attributed to the immersive, interactive features of AR-based learning. Learners could visualize sentence structures and manipulate grammatical components, enhancing their syntactic awareness. The feedback mechanisms embedded in AR applications allowed for immediate correction, reinforcing rule retention. The smaller gains observed in the control group imply that conventional grammar instruction, while effective to some extent, lacks the engagement and contextual reinforcement offered by AR technology.

The overall results align with cognitive learning theories suggesting that multimodal input enhances information encoding and retrieval. Learners' exposure to visual, auditory, and kinesthetic stimuli during AR tasks supported deeper processing of grammatical patterns. This indicates that AR does not merely supplement traditional methods but reshapes how learners internalize grammar rules through experiential interaction.

Secondary data from learner perception surveys showed high levels of satisfaction and engagement in the experimental group. Eighty-seven percent of participants agreed that AR made grammar learning more enjoyable, and 82% reported better understanding of grammar usage in real-life contexts. In contrast, 60% of control group participants found grammar lessons repetitive and difficult to retain.

**Figure 1.** Learner perception survey results

Qualitative data from teacher observations also indicated noticeable differences in classroom dynamics. Learners using AR were more collaborative and actively discussed grammatical forms, while traditional classes were largely teacher-centered. These behavioral observations corroborate the quantitative findings, highlighting AR's ability to foster autonomous and peer-supported learning environments.

Inferential statistics were conducted using paired-sample t-tests and ANCOVA to determine the significance of the observed differences. Table 2 summarizes the results. The t-test revealed a

statistically significant improvement in the experimental group ( $t(39) = 14.27, p < 0.001$ ), while the control group showed a smaller but significant improvement ( $t(39) = 6.85, p < 0.05$ ). ANCOVA analysis confirmed that the difference in post-test scores between the groups remained significant even after controlling for pre-test differences ( $F(1,77) = 22.36, p < 0.001$ ).

**Table 2.** Inferential statistical results

Test Type	Group	t / F Value	p Value	Significance
Paired-sample t-test	Experimental (AR)	14.27	<0.001	Significant
Paired-sample t-test	Control (Traditional)	6.85	<0.05	Significant
ANCOVA	Between Groups	22.36	<0.001	Significant

These findings establish that the AR-integrated instruction significantly enhanced grammatical proficiency beyond what traditional methods achieved. The effect size (Cohen's  $d = 1.12$ ) indicated a large impact of AR learning on grammar acquisition. The correlation analysis revealed a strong positive relationship between learners' engagement scores and their grammar performance ( $r = 0.71, p < 0.01$ ). Learners who reported higher satisfaction with AR activities also tended to show greater post-test improvement. This suggests that affective engagement and cognitive outcomes are interlinked within AR environments.

The relationship between time spent interacting with AR materials and learning gains was also significant ( $r = 0.63, p < 0.01$ ). Students who engaged more frequently with AR tasks exhibited higher retention and fewer grammatical errors. This relationship underlines the importance of sustained exposure and practice within digital learning ecosystems. A case study involving two high-achieving and two low-achieving students provided insights into individual learning trajectories. High-achieving learners described AR as "a visual grammar coach" that helped them see how words and tenses connect. Low-achieving learners initially struggled with navigation but later reported improved comprehension once they adjusted to the interface.

Teacher interviews indicated that AR enhanced classroom inclusivity by supporting visual learners and reducing reliance on linguistic explanations alone. The technology bridged the comprehension gap between students with different proficiency levels, creating a more equitable learning environment. The integration of quantitative and qualitative findings highlights the dual benefits of AR-based grammar instruction: measurable performance improvement and enhanced learner engagement. The technology's capacity to transform abstract grammatical concepts into interactive visual experiences proved crucial in supporting deep learning. Teachers observed greater participation and reduced anxiety during grammar tasks, which are often considered intimidating by ESL learners.

Learners' reflective journals reinforced this pattern. Many participants expressed increased confidence in using grammar in authentic contexts. This affective shift from rote memorization to conceptual understanding demonstrates AR's potential to humanize and personalize language learning experiences. The results indicate that AR-based instruction can significantly improve ESL learners' grammatical accuracy, engagement, and motivation. The interactive and multimodal nature of AR supports both cognitive and affective dimensions of language learning. The findings suggest that technology-mediated grammar instruction can move beyond mechanistic drills toward meaning-oriented, learner-centered approaches.

The study's outcomes confirm that AR holds pedagogical promise for ESL education, particularly in fostering autonomous and experiential learning. The combination of statistical gains and qualitative validation provides a robust argument for adopting AR as a complement to

traditional grammar teaching methods, marking a step toward immersive and adaptive language learning paradigms.

The findings of this mixed-methods study revealed that Augmented Reality (AR) significantly enhanced grammar learning outcomes among ESL students by increasing engagement, comprehension, and retention. Quantitative results demonstrated a statistically significant improvement in post-test grammar scores for the experimental group using AR applications compared to the control group engaged in traditional instruction. The data indicated that visualized grammar concepts and interactive simulations facilitated better understanding of abstract grammatical structures such as tenses and conditional clauses. Learners reported higher motivation and enjoyment when interacting with 3D grammar models, suggesting that AR fosters a more immersive and student-centered learning environment.

Qualitative insights supported these statistical results. Student interviews and classroom observations indicated that AR-based grammar lessons encouraged exploratory learning and collaborative discussions, which deepened grammatical awareness. Learners expressed that the ability to manipulate virtual objects, observe contextual examples, and receive instant feedback helped them visualize grammar rules in authentic contexts. Teachers noted that AR tools allowed for differentiated instruction, catering to various learning styles while sustaining learner curiosity. Overall, the study confirmed that AR integration transforms grammar teaching from rule-based memorization into experiential learning driven by interactivity and visualization.

The results align with previous research emphasizing the pedagogical value of AR in language education. Studies such as (Cruz dkk., 2023) and (Binothman dkk., 2024) demonstrated that AR applications improve engagement and conceptual understanding by combining visual, auditory, and kinesthetic modalities. This study extends those findings by focusing specifically on grammar acquisition a linguistic area often considered less tangible and more abstract compared to vocabulary or pronunciation. The data affirm that AR can bridge the gap between conceptual grammatical forms and their functional use in communicative contexts.

Distinctly, the current study differs from earlier research by adopting a mixed-methods approach that integrates learner analytics with narrative reflections, offering a more holistic perspective on learning processes. While previous studies mainly focused on short-term motivation and engagement, this research explored long-term comprehension and learner autonomy. The combination of quantitative grammar mastery data and qualitative student feedback provides richer insight into how AR enhances not just understanding but also learner confidence and metacognitive awareness in grammar use.

The findings indicate a paradigm shift in how grammar can be effectively taught in second language classrooms. The success of AR integration reflects a transition from form-focused instruction toward interaction-driven pedagogy, where learners construct meaning through contextual exploration rather than rote memorization. The enhancement of learners' conceptual visualization abilities signifies that grammar learning becomes more meaningful when abstract linguistic concepts are grounded in dynamic visual and situational contexts.

This pattern also signifies that technology, when used pedagogically rather than merely as a novelty, can reshape how linguistic competence develops. Learners no longer perceive grammar as a mechanical process but as an interactive system tied to communication, culture, and cognition. The study highlights the importance of embodiment in learning the process by which physical interaction with digital objects strengthens conceptual understanding. This embodied engagement may redefine the future of grammar pedagogy in ESL education by emphasizing active learning and cognitive immersion.

The implications of these findings extend beyond grammar instruction and inform broader educational practices in technology-enhanced learning. AR offers opportunities for personalized and adaptive instruction, where learners can progress at their own pace while interacting with contextualized examples. Teachers can utilize AR data analytics to monitor progress, identify misconceptions, and provide targeted feedback, thus bridging gaps in understanding more efficiently. The interactive nature of AR aligns with constructivist learning theories, which posit that learners acquire knowledge best through active exploration and self-discovery.

The integration of AR into English language classrooms also addresses motivational challenges commonly faced by ESL learners. The immersive experience of AR fosters intrinsic motivation by turning learning into a playful yet intellectually engaging process. Institutions can leverage these results to develop curriculum models that integrate AR-based grammar instruction within blended learning environments, fostering equitable access and sustaining engagement in both physical and virtual classrooms.

The positive outcomes observed can be attributed to the multisensory and immersive nature of AR, which supports dual coding theory and cognitive load reduction. Grammar, traditionally taught through text and repetition, often overwhelms learners' working memory. AR mitigates this by offering visual anchors and contextual cues that make abstract grammatical rules easier to process. Learners benefit from simultaneous visual and linguistic representation, enhancing both comprehension and recall. The findings confirm that multimodal integration enhances cognitive processing efficiency, leading to deeper and longer-lasting learning.

Another explanatory factor lies in the social interaction facilitated by AR. The collaborative features of AR platforms encouraged peer dialogue and cooperative problem-solving, reinforcing social constructivist principles. Learners negotiated meaning and discussed grammatical patterns within shared AR environments, transforming passive learning into active co-construction of knowledge. This interactive social engagement explains why learners demonstrated stronger retention and greater willingness to apply grammar rules communicatively after AR exposure.

The findings call for strategic implementation of AR technology within language education frameworks. Future curriculum design should move beyond experimental applications toward systemic integration of AR tools for grammar, vocabulary, and discourse instruction. Teachers need professional development in digital pedagogy to maximize AR's pedagogical potential and ensure alignment with learning objectives. Institutions should consider investing in accessible AR infrastructure that supports mobile and low-cost solutions to promote equity in digital learning.

Further research should explore longitudinal effects of AR-assisted grammar learning on communicative competence and writing accuracy. Studies could examine cross-cultural or multilingual contexts to understand how AR mediates grammatical learning among diverse learner populations. Investigating the intersection of AR with artificial intelligence and adaptive feedback systems would provide deeper insights into how real-time learner data can personalize instruction. As AR technologies evolve, their integration into language learning will likely redefine not only how grammar is taught but also how learners experience and internalize language as a living, interactive system.

## CONCLUSION

The most significant finding of this study lies in the demonstration that Augmented Reality (AR) serves not merely as a supplementary instructional tool but as a transformative medium in grammar learning for ESL students. The study reveals that AR facilitates the visualization of abstract grammatical structures, allowing learners to interact directly with linguistic elements

through immersive, contextualized tasks. This interactivity bridges the cognitive gap between rule-based instruction and practical language use, leading to substantial improvements in grammatical accuracy and learner engagement. The distinct contribution of this research is its empirical evidence showing that learners exposed to AR not only performed better statistically but also developed a deeper conceptual understanding of grammar, indicating that AR effectively supports both analytical and intuitive aspects of language acquisition.

The research contributes both conceptually and methodologically to the field of technology-enhanced language learning. Conceptually, it proposes a pedagogical model where grammar instruction shifts from text-bound explanation toward experiential and spatial interaction. This model redefines grammatical competence as an embodied learning process mediated by technology rather than a purely cognitive construct. Methodologically, the study validates a mixed-methods approach integrating quantitative performance analysis and qualitative learner experience data within the context of AR-mediated instruction. This dual-layer analysis establishes a framework for evaluating educational technologies not only in terms of learning outcomes but also in terms of learner perception, motivation, and interaction dynamics offering a replicable model for future AR-based educational research.

The study acknowledges certain limitations that inform future investigations. The research was conducted with intermediate-level ESL learners in a controlled institutional environment, which may restrict the generalizability of results to other proficiency levels or informal learning contexts. The relatively short duration of the intervention limits the ability to assess long-term retention and transferability of grammatical knowledge. Future research should therefore explore longitudinal designs to evaluate sustained learning effects and extend analysis to different linguistic domains such as pragmatics or discourse. Expanding the scope to include adaptive AR systems powered by artificial intelligence could further refine personalization and interactivity. Cross-cultural comparisons and integration with virtual or mixed reality environments would also enrich the understanding of immersive grammar learning across diverse educational ecosystems.

## AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

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