



Innovating Biology Education through Google Sites-Integrated Problem-Based Learning to Enhance Students' Critical Thinking Skills and Learning Outcomes

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Abstract: This study aims to develop Google Sites-based learning media integrated with the Problem-Based Learning (PBL) model on the topics of plant and animal tissues, with the goal of improving students' critical thinking skills and biology learning outcomes. The research followed the ADDIE development model, encompassing five systematic stages: Analysis, Design, Development, Implementation, and Evaluation. The study involved 35 Grade XI science students at SMA Negeri 3 Samarinda, Indonesia. The research instruments comprised expert validation sheets, practicality questionnaires, critical thinking tests, and learning achievement assessments. Data were analyzed using a mixed-method approach, combining quantitative and qualitative techniques through descriptive statistics, paired-samples t-tests, and N-Gain analysis. The results indicated that the developed media achieved a very high level of feasibility according to expert validation, with average scores of 93.75% from media experts, 91.25% from subject matter experts, and 95.00% from language experts. Practical assessments received very positive responses from teachers (95.00%) and students (91.33%), demonstrating that the media was user-friendly, engaging, and functional. Furthermore, the media effectively improved students' critical thinking skills and learning outcomes, with an overall N-Gain of 0.84 (high category) and critical thinking indicator gains ranging from 0.71 to 0.86. A key innovation was the integration of an interactive discussion feature using Canva within Google Sites, which promoted collaboration and meaningful learning. In conclusion, the Google Sites-based PBL media was highly feasible, practical, and effective for improving students' critical thinking skills and learning outcomes in biology.

Keywords: Critical thinking; Google sites; Learning outcomes; Plant and animal tissues; Problem-based learning

Introduction

Critical thinking is one of the essential skills students must master in 21st-century education to navigate increasingly complex global challenges. It serves as the foundation for scientific reasoning and problem-solving, enabling learners to evaluate information objectively and make rational decisions (Akbar, 2023; Facione, 2015). In biology education,

critical thinking plays a crucial role in helping students interpret biological phenomena, analyze the relationship between structure and function, and apply biological concepts to real-life contexts (Duran & Dökme, 2016). Recent studies emphasize that critical thinking contributes to the development of scientific literacy, creativity, and innovation, which are key competencies in modern education (Hutsalo & Ordanovska, 2024; Primasari et al., 2020). Moreover, enhancing students'

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critical thinking has been shown to positively influence their academic performance, particularly in mastering complex and applied biological concepts (Lukitasari et al., 2019; Ratnasari et al., 2025). Strengthening both critical thinking and learning outcomes is therefore fundamental to preparing a scientifically literate generation capable of adapting to rapid changes in the digital era.

Despite its recognized importance, students' critical thinking and learning outcomes remain underdeveloped in classroom practice. Preliminary observations at SMA Negeri 3 Samarinda revealed that biology instruction is still largely dominated by conventional lecture-based methods, which emphasize rote memorization over inquiry and exploration. Such teacher-centered approaches restrict opportunities for problem-solving, reflection, and active engagement, thereby limiting the development of higher-order cognitive skills (Listiana & Loka, 2023; Purnama et al., 2024). Giri et al. (2019) further noted that these patterns contribute to passive learning behaviors, superficial understanding, and low conceptual retention. The limited integration of interactive technology in biology education exacerbates the problem, as many teachers continue to rely on static tools, such as PowerPoint slides or printed modules, which do not support collaborative or experiential learning. Consequently, students often lack opportunities to engage with real-world problems, perform investigative tasks, or receive immediate formative feedback. This situation underscores the urgent need for innovative, technology-enhanced learning media that are pedagogically sound, promote active participation, foster critical thinking, and improve both conceptual understanding and overall learning outcomes.

According to Facione (2015), critical thinking develops best in learning environments that encourage students to analyze, evaluate, and synthesize information through reflective experiences. One pedagogical model proven to cultivate these skills is Problem-Based Learning (PBL), which positions students as problem solvers in authentic contexts, thereby stimulating higher-order thinking (Hafizah et al., 2024; Wardani & Fiorintina, 2023). Through PBL, learners are trained to identify problems, formulate hypotheses, gather relevant information, and test solutions based on empirical evidence. Studies by Sevtia et al. (2022) and Nurdin et al. (2023) have revealed that implementing PBL enhances both critical thinking and learning outcomes by promoting active engagement, collaboration, and real-world application of concepts. Furthermore, the integration of interactive digital platforms such as Google Sites has been shown to strengthen these outcomes by providing spaces for exploration, discussion, and self-reflection (Susanti et

al., 2023). Thus, combining technology-based media with problem-based pedagogy serves as a key strategy for fostering active, collaborative, and impactful learning experiences.

Digital learning media offer powerful solutions to bridge pedagogical gaps by enhancing interactivity, engagement, and accessibility. Studies have shown that technology-based learning environments can significantly improve students' critical thinking and academic achievement when designed with pedagogical alignment (Sevtia et al., 2022; Pinilih et al., 2024). Among available platforms, Google Sites has emerged as an effective tool for creating web-based, interactive, and personalized learning environments (Rusli et al., 2023). Google Sites allows educators to design structured and visually engaging learning spaces where content can be seamlessly integrated with multimedia elements such as videos, images, interactive quizzes, and embedded Google Forms for formative assessment. In addition, it supports the creation of collaborative discussion forums and links to external resources, enabling real-time interaction and peer-to-peer engagement within a single, accessible interface (Gesly et al., 2023). This aligns with Yot-domínguez et al. (2017) and Pratiwi et al. (2023), who emphasize that web-based platforms foster learner autonomy, flexibility, and student-centered instruction. Furthermore, the integration of multimedia resources, interactive tools, and online discussion spaces promotes multimodal learning, knowledge construction, and active participation, making Google Sites a comprehensive platform for implementing inquiry-based and problem-based learning approaches (Nurwita et al., 2024).

Problem-Based Learning (PBL) has been widely recognized as an effective instructional strategy for enhancing critical thinking, conceptual understanding, and academic performance through engagement with authentic, real-world problems (Aisy & Trisnowati, 2024; Asiyah et al., 2021). At its core, PBL emphasizes student-centered inquiry, where learners actively identify, analyze, and propose solutions to complex problems, fostering self-directed learning, collaboration, and reflective thinking. In biology education, PBL encourages scientific reasoning by connecting theoretical knowledge with investigative practices, such as experiments, data interpretation, and case-based scenarios, allowing students to apply concepts in meaningful contexts (Shofiya & Wulandari, 2020). Furthermore, PBL promotes higher-order cognitive skills, including analysis, evaluation, and synthesis, by requiring learners to integrate prior knowledge, assess evidence, and justify their solutions. Recent studies also indicate that integrating PBL with digital learning environments can further enhance engagement, reflection, and learner autonomy (Sevtia et al., 2022;

Gesy et al., 2023). By leveraging technology, PBL can incorporate interactive resources, multimedia simulations, and collaborative platforms, providing flexible and personalized learning pathways. Therefore, implementing PBL in digital contexts represents a promising innovation for developing students' higher-order thinking skills, scientific literacy, and overall learning achievement in the 21st century.

The unique contribution of this study lies in the development of a Google Sites-based learning medium integrated with PBL and enhanced by an interactive Canva-based discussion forum. This innovation allows students to engage in collaborative dialogue, share ideas, and identify contextual problems collectively features often absent in previous Google Sites-based media, which typically focused on individual activities. The integration aims to create a collaborative and reflective learning environment that deepens conceptual understanding, strengthens critical thinking, and improves learning outcomes. However, despite increasing interest in technology-enhanced PBL, limited research has explored the integration of Google Sites-based media with the PBL model in biology education contexts.

In response to this research gap, the present study aims to develop a Google Sites-based learning medium integrated with the Problem-Based Learning model and supported by an interactive Canva discussion feature to foster collaboration, analysis, and reflection among students. Specifically, this study seeks to (1) develop a feasible and practical PBL-based Google Sites learning medium and (2) evaluate its effectiveness in improving students' critical thinking skills and biology learning outcomes.

Method

This research applied a Research and Development (R&D) design using the ADDIE model, which consists of five systematic stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2019; Saprudin et al., 2025). The ADDIE framework was selected because it provides a structured, iterative, and flexible approach for developing, validating, and refining instructional media within educational settings. The research was conducted at SMA Negeri 3 Samarinda, Indonesia, involving 35 students from Grade XI MIPA during the 2024/2025 academic year. Participants were selected through purposive sampling, based on representativeness, active participation, and readiness to engage in digital-based biology learning activities.

The development process included expert validation involving three groups of specialists: media experts, subject matter experts, and language experts.

Each group evaluated the feasibility of the developed learning media based on three key dimensions design quality, content accuracy, and language clarity.

The feasibility assessment employed a four-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree), following the guidelines of Sugiyono (2020). The obtained scores were then converted into percentages using the following formula:

$$P = \frac{\text{Obtained Score}}{\text{Maximum Score}} \times 100\% \tag{1}$$

The resulting percentage values were interpreted according to the feasibility criteria presented in Table 1.

Table 1. Criteria for Feasibility and Practicality Assessment

Percentage Range (%)	Category
90-100	Very Feasible/ Very Practical
75-89	Feasible/ Practical
65-74	Fairly Feasible/ Fairly Practical
55-64	Less Feasible/ Less Practical
0<55	Very Unfeasible

The practicality test was conducted with biology teachers and students using a structured questionnaire to evaluate the usability, attractiveness, and usefulness of the developed learning media. The interpretation of practicality levels followed the same percentage criteria as presented in Table 1. Data obtained from expert validation and practicality questionnaires were analyzed descriptively to determine the feasibility and user acceptance of the learning media.

The effectiveness of the learning media was examined using a pretest-posttest design that measured students' learning outcomes and critical thinking skills. The critical thinking test was developed based on the indicators proposed by Facione (2015), which include interpretation, analysis, evaluation, inference, and explanation. Differences in students' scores before and after using the media were analyzed using the N-Gain test and paired-sample t-test to determine the degree of improvement in learning outcomes and critical thinking abilities.

The effective analysis was conducted by comparing students' pretest and posttest scores, with the improvement level calculated using the N-Gain formula as follows:

$$\text{N-Gain} = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Maximum score} - \text{Pretest score}} \tag{2}$$

The average normalized gain (N-Gain) scores were converted into percentages and then classified according to the interpretation criteria of N-Gain effectiveness, as presented in Table 2.

Table 2. N-Gain Interpretation Criteria

N-Gain Value	Category
$g > 0.7$	High
$0.3 \leq g \leq 0.7$	Medium
$g \leq 0.3$	Low

The criteria for interpreting the effectiveness of the media can be determined based on students' critical thinking skills, as reflected in the N-Gain values presented in Table 3.

Table 3. Interpretation of N-Gain Effectiveness

Percentage (%)	Category
$g < 40\%$	Not Effective
$40\% \leq g < 55\%$	Less Effective
$56\% \leq g \leq 75\%$	Moderately Effective
$g < 76\%$	Effective

This development study utilized two types of data: quantitative and qualitative. Quantitative data were analyzed using descriptive statistical methods, while qualitative data consisting of expert comments, suggestions, and feedback were examined through a descriptive qualitative approach. The qualitative findings served as the basis for revising and refining the product to ensure it met the expected standards. Both types of data were analyzed complementarily to assess the feasibility, practicality, and effectiveness of the learning media. The Google Sites-based learning media integrated with the Problem-Based Learning (PBL) model, designed to enhance students' critical thinking and learning outcomes, was considered feasible if it achieved a "valid" category based on the validation results from six experts: media specialists, content experts, and language experts. Media that met this validity criterion were deemed ready for implementation in biology instruction.

This study was conducted in accordance with established educational research ethics. Ethical approval and research permission were obtained from the principal and biology teachers of SMA Negeri 3 Samarinda, with informed consent provided by all participating students prior to data collection.

Result and Discussion

Results

A Google Sites-based learning media integrated with the Problem-Based Learning (PBL) model was successfully developed as an interactive, easily accessible, and student-centered digital platform. This media comprises several key components: (1) a homepage featuring the learning objectives and navigation menu, (2) learning materials presented through a combination of text, images, and videos, (3)

digital student worksheets (E-LKPD) containing problem-based activities, (4) quizzes and integrated Google Forms for formative assessment, and (5) an interactive discussion forum via Canva designed to facilitate collaborative learning and peer-to-peer discussions.

The media was developed based on the PBL syntax, which includes stages of problem orientation, independent investigation, group discussion, solution development, and learning reflection. Within the digital worksheets, students are guided to analyze contextual cases such as disorders in plant and animal tissues, and then collaboratively construct scientific solutions through activities in the E-LKPD or linked online discussion forums. This design not only emphasizes conceptual understanding but also cultivates critical thinking and problem-solving skills.

The media is accessible on both smartphones and laptops, allowing flexible use in and outside the classroom. Figure 1 illustrates the main interface and learning flow of the developed Google Sites-based learning media.



Figure 1. Homepage of the Google Sites-based learning media (Note: The Google Sites-based learning media developed in this study can be accessed and downloaded via the following link: <https://sites.google.com/view/sman3samarinda-mediainteraktif?usp=sharing>)

The feasibility, practicality, and effectiveness of the developed media were evaluated through a series of expert validations, user assessments, and analyses of student performance. The results of these evaluations are presented in the following sections.

The validation process involved three groups of expert media experts, namely content experts, and language experts to assess the feasibility and quality of

the developed learning media. The validation results are presented in Table 4.

The findings indicate that the developed media met all feasibility standards, achieving an overall average score of 93.33%, which is categorized as “highly feasible.” The consistency of layout, scientific accuracy, and appropriateness of language demonstrate that this Google Sites-based media is ready for classroom implementation.

Table 4. Expert validation results of Google Sites-Based Learning Media

Validator Type	Average Score	Percentage	Category
Media Expert	3.75	93.75%	Very Feasible
Content Expert	3.65	91.25%	Very Feasible
Language Expert	3.8	95%	Very Feasible
Average	3.73	93.33%	Very Feasible

The practicality of the media was evaluated by teachers and students using structured questionnaires

Table 6. Results of Learning Outcomes Test (Pretest–Posttest)

Class Type	Pretest Mean	Posttest Mean	Gain	N-Gain	Category
Experimental (n = 35)	47.94	90.94	43	0.84	High
Control (n = 35)	48.29	75.54	27.25	0.52	Medium

The data indicate that the experimental class experienced a higher mean gain (N-Gain = 0.84, high category) compared to the control class (N-Gain = 0.52, medium category). This suggests that integrating Google Sites with the PBL model effectively enhanced

assessing ease of use, attractiveness, and learning efficiency. The results of these evaluations are summarized in Table 5.

Table 5. Practicality Test Results

Respondent Type	Average Score	Percentage	Category
Teacher	3.8	95%	Very Practical
Students (n = 35)	3.65	91.33%	Very Practical
Average	3.73	93.17%	Very Practical

The results show that both teachers and students rated the learning media as “highly practical.” Teachers reported that the media was efficient and supported student-centered learning, while students noted that it was engaging, easy to use, and motivating due to its interactive visual design.

The effectiveness of the developed media was assessed by comparing students’ pretest and posttest scores in both the experimental and control groups. The results of this analysis are presented in Table 6.

students’ conceptual understanding and learning achievement.

Students’ critical thinking skills were assessed using Facione’s (2015) indicators, which include interpretation, analysis, evaluation, and inference. The results of these improvements are presented in Table 7.

Table 7. Improvement in Critical Thinking Indicators (N-Gain Results)

Indicator	Pretest Mean	Posttest Mean	N-Gain	Category
Interpretation	57.14	88.57	0.73	High
Analysis	47.14	92.14	0.85	High
Evaluation	44.64	92.14	0.86	High
Inference	48.57	85	0.71	High
Average	49.37	89.46	0.79	High

The results indicate that all aspects of critical thinking improved significantly, with N-Gain values ranging from 0.71 to 0.86. The evaluation indicator achieved the highest score (0.86), reflecting an enhanced ability among students to assess, compare, and justify solutions based on data interpretation and problem analysis. The overall average N-Gain of 0.79 demonstrates that the developed media effectively fostered higher-order cognitive skills through inquiry-based and technology-integrated learning.

Overall, the Google Sites-based learning media integrated with the Problem-Based Learning (PBL) model was classified as highly feasible, highly practical, and highly effective. The media not only improved

students’ conceptual understanding and learning achievement but also significantly enhanced their critical thinking skills. Furthermore, the integration of an interactive Canva-based discussion forum successfully promoted collaborative learning, critical reasoning, and meaningful engagement, aligning with the principles of 21st-century education and the Indonesian Merdeka Curriculum framework.

Discussion

The development of Google Sites-based learning media integrated with the Problem-Based Learning (PBL) model was carried out systematically following the ADDIE framework. Each stage, namely analysis,

design, development, implementation, and evaluation, was aimed at producing a pedagogically grounded and empirically validated product. This process emphasized identifying learner needs, iterative prototype refinement, and expert validation to ensure alignment with curriculum goals and learner characteristics. The study extends previous work by integrating principles of digital constructivism and multimedia learning, particularly through the inclusion of interactive design features. Consistent with Branch (2019) and Reiser et al. (2018), the ADDIE model supports iterative, learner-centered development processes, making it especially suitable for educational innovation.

Integrating Google Sites into the media design enabled multimodal learning by combining text, video, quizzes, and interactive links to support engagement across diverse cognitive styles. The findings indicate that multimodal presentation helps learners grasp abstract biological concepts more concretely and contextually. This aligns with Mayer's (2020) Cognitive Theory of Multimedia Learning, which highlights that combining verbal and visual channels enhances cognitive processing and knowledge retention. Within this context, the PBL syntax, ranging from problem orientation to investigation, collaboration, and reflection was embedded directly into the media's structure to stimulate scientific reasoning and inquiry. This integration proved effective in increasing student engagement throughout the learning process. These results reinforce (Wardani et al., 2024) assertion that PBL environments nurture reflective reasoning and sustained knowledge construction. Moreover, consistent with Hakim et al. (2023) and Sundari et al. (2024), this study confirms the flexibility and effectiveness of Google Sites in promoting interdisciplinary engagement and learning outcomes. Unlike previous research, however, this integration of Google Sites and PBL was not limited to content delivery but functioned as an interactive platform that fostered collaboration, discussion, and digital reflection, thereby reinforcing the pedagogical essence of PBL itself.

Expert validation results showed that the developed Google Sites-based media met all feasibility standards, with an average score of 93.33%, categorized as highly feasible. The integration of visual design, content accuracy, and language clarity resulted in media that were not only aesthetically appealing but also pedagogically sound. Consistent layout and intuitive navigation helped students focus on the learning content without experiencing excessive cognitive load, supporting the principles of Clark et al. (2016) Cognitive Theory of Multimedia Learning. Beyond technical soundness, the media also demonstrated strong contextual relevance to biology instruction, integrating authentic materials and interactive elements that foster

inquiry and reflection. The high validation score indicates that the product is ready for classroom implementation to enhance engagement, critical thinking, and learner autonomy. These findings align with prior studies (Fitri & Setiawan, 2023; Laufer et al., 2021; Safira & Taiyeb, 2018) while contributing new evidence that problem-based, interactive interface design within Google Sites can directly enhance both pedagogical and cognitive effectiveness.

The practicality assessment revealed very high acceptance levels among teachers and students, with mean scores exceeding 90%. Teachers reported that the platform simplified learning resource management and facilitated the implementation of problem-based instruction, while students found it visually engaging, easy to use, and motivating (Anam et al., 2023). This practicality stems not only from its intuitive interface but also from its responsive and interactive design, which supports adaptive and self-directed learning an approach consistent with Mayer's (2020) cognitive multimedia principles emphasizing verbal visual integration for optimal cognitive engagement. Similarly, OECD (2021) and Listiana et al. (2023) emphasized that inclusive, interactive digital tools enhance learning participation across diverse contexts. The cross-device accessibility of Google Sites (Sun & Chen, 2016) further supports learner autonomy and flexibility in line with Indonesia's Merdeka Belajar framework. Hence, the integration of Google Sites with the PBL model yields a learning medium that is not only operationally efficient but also pedagogically relevant, supporting contextualized, flexible, and learner-centered education.

The effectiveness analysis demonstrated a high N-Gain score of 0.84, indicating a substantial improvement in student learning outcomes. The media successfully facilitated scientific reasoning and deeper conceptual understanding by integrating text, videos, quizzes, and problem-based worksheets that helped students connect abstract biological concepts to real-world phenomena. The PBL structure guided learners through orientation, investigation, and reflection stages, reinforcing meaningful knowledge transfer (Hafizah et al., 2024). Classroom observations showed that students became more independent, analytical, and reflective, suggesting that the media acted not merely as a delivery tool but as a facilitator of knowledge construction and meaningful learning. These results are consistent with findings by Gesy et al. (2023), Nurwita et al. (2024), and Sevtia et al. (2022), who reported that web-based PBL approaches significantly improved conceptual mastery, motivation, and scientific learning outcomes. Furthermore, digital formats encourage collaboration and self-regulated learning (Anderson, 2020; Chelghoum, 2017) while strengthening digital literacy, which amplifies PBL's impact on science learning (Istiqomah & Sipahutar, 2025;

Sumiati et al., 2025). Therefore, the integration of interactive technology and PBL effectively fosters meaningful, reflective, and student-centered biology learning.

Beyond improving learning outcomes, the media also demonstrated a significant impact on students' critical thinking skills, with N-Gain values ranging from 0.71 to 0.86, with the highest on the evaluation indicator (0.86). This indicates that students not only understood the concepts but were also able to evaluate information and construct evidence-based arguments. The improvement can be attributed to the media's design, which emphasizes problem-solving and collaborative reflection to stimulate higher-order thinking. The PBL stages, namely problem identification, investigation, and reflection, encouraged metacognitive engagement as students analyzed relationships among concepts, evaluated data, and drew independent conclusions. This learning process aligns with Vygotsky's (2019) concept of the zone of proximal development, in which social interaction and collaboration play key roles in cognitive growth. Additionally, the Canva-based discussion forum embedded within the media functioned as a digital social space that promoted argumentation, feedback, and reflective dialogue among peers. Classroom observations revealed that students became more confident in expressing ideas and critically responding to others' viewpoints, enhancing both critical thinking and collaborative communication. These findings are consistent with Wahyuningtyas et al. (2025) and Iwan et al. (2024), who found that technology integration strengthens analytical and scientific literacy skills, and they extend the work of Nugroho et al. (2024) and Wardani et al. (2024), who emphasized that Google Sites-based PBL enhances higher-order thinking skills aligned with OECD's (2021) 4Cs framework critical thinking, creativity, collaboration, and communication. Thus, the improvement in students' critical thinking resulted not merely from technology use but from pedagogical design that deliberately integrates interactivity, collaboration, and reflection into an active, contextual, and digital learning ecosystem.

Overall, the integration of Google Sites with the PBL model represents a robust pedagogical innovation in biology education. Its high feasibility, practicality, and effectiveness confirm its capacity to transform conventional teacher-centered instruction into interactive, student-driven inquiry aligned with Merdeka Belajar. The study extends the work of Hakim et al. (2023) by embedding Canva-assisted collaboration as a novel feature that strengthens engagement and cognitive depth. Collectively, these findings contribute to the growing literature on digital investigative learning and offer a practical framework for applying

constructivist principles in web-based instructional design.

Conclusion

The study concludes that the developed Google Sites-based learning media integrated with the Problem-Based Learning (PBL) model significantly enhances students' critical thinking skills and biology learning outcomes. The high N-Gain score (0.84) and consistent improvements across critical thinking indicators (0.71–0.86) demonstrate the media's strong effectiveness in promoting analytical reasoning, evaluation, and inference. The inclusion of a Canva-based interactive discussion feature represents a novel pedagogical innovation that fosters digital collaboration, engagement, and reflective learning, distinguishing this study from previous research. Theoretically, the findings support constructivist and multimedia learning principles, demonstrating that combining PBL with interactive web technology facilitates deeper conceptual understanding and learner autonomy. Furthermore, the developed media aligns with Indonesia's Merdeka Curriculum by cultivating 21st-century competencies, namely critical thinking, creativity, collaboration, and independence through meaningful, student-centered digital learning experiences.

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Author Contributions

M.Z.R.A.: conceptualized the research, research procedures, analyzed the data and wrote the article; L.S., S., A., K.P.C.: supervised the writing of the article, reviewed and validated the research instruments used.

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Conflicts of Interest

The authors declare no conflict of interest.

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