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Implications of Science Learning Models for Enhancing Students' Science Process Skills in Elementary Schools in the Digital Era

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Abstract: This study investigates the implications of science learning models for strengthening elementary students' Science Process Skills (SPS) in the digital era. The research addresses the problem of uneven development of SPS indicators, particularly higher-order and language-intensive skills, in primary science classrooms. The study aims to describe the implementation of science learning models, the profile of students' SPS, the integration of digital technology, and assessment practices in Grade V science learning. A qualitative case study was conducted in two public elementary schools in Tanjung pinang Timur using purposive sampling. Data were collected through classroom observations, semi-structured interviews with two teachers and four students, and documentation, and were analyzed using an interactive model of data reduction, data display, and conclusion drawing. The findings reveal that science instruction is dominated by group discussions and hands-on experiments, with the emerging use of project-based learning. Students demonstrate strong foundational SPS (observing, classifying, measuring) but show weaknesses in predicting, hypothesizing, concluding, and communicating due to confidence and language barriers. Digital media support conceptual understanding and engagement but are limited by device availability and preparation time. Assessment practices remain largely product-oriented and group-based. The study concludes that strengthening SPS requires pedagogy-led technology integration, targeted scaffolding for scientific reasoning and communication, and indicator-based assessment aligned with the Kurikulum Merdeka.

Keywords: Digital era; Science learning model; students' science process skills

Introduction

Rapid advances in information and communication technologies have shifted educational paradigms from teacher-centered transmission to student-centered inquiry, collaboration, and problem solving. Within this transformation, teachers act as designers of adaptive learning experiences and facilitators of students' digital literacy; consequently, sustained professional development is indispensable to meet twenty-first-century competency demands (Caswita & Noviyani, 2023). Aligned with the Kurikulum Merdeka emphasis on contextual and project-based learning, strengthening teachers' professional capacity is critical so that primary science education (IPA) not only conveys concepts but also cultivates scientific habits of mind and resilient learning dispositions.

In primary science, the digital era presents both challenges and opportunities for developing pupils' scientific inquiry from an early age. Science learning is expected to nurture initiative, hypothesis formulation, critical reasoning, and evidence-based argumentation. Scientific Process Skills (KPS) therefore constitute a central axis: through KPS, learners acquire, elaborate, and apply scientific concepts, principles, and laws in meaningful ways that are responsive to real-world

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phenomena (Hartini et al., 2018; Widyaningsih et al., 2020). This focus coheres with twenty-first-century learning needs to prepare creative, adaptive, and competitive citizens in rapidly evolving digital ecosystems.

Conceptually, KPS encompass cognitive/intellectual, manual/psychomotor, and social-communicative dimensions. They are evidenced in the capacity to conduct scientific work, communicate findings, and exhibit scientific attitudes (Pertiwi et al., 2020). At the basic level, indicators include observing, classifying, measuring, predicting, concluding, designing experiments, and communicating; at the integrated level, these indicators are orchestrated within more complex scientific tasks (Candra & Hidayati, 2020; Riswanto & Ayu, 2017). Reliable assessment instruments are needed from the outset of primary schooling to monitor growth across these indicators with accuracy and fairness.

A range of pedagogical models function as levers to strengthen KPS—among them Problem-Based Learning (PBL), Project-Based Learning (PJBL), inquiry/guided inquiry, discovery learning, and STEM-integrated approaches. Empirical studies show that PBL and inquiry heighten students' ability to formulate problems, generate predictions, design experiments, and interpret data (Handayani et al., 2021; Indah et al., 2023; Wulandari & Oktaviani, 2024). STEM integration enriches authentic contexts and fosters the 4Cs of critical thinking, creativity, collaboration, and communication (Wicaksono, 2020), while discovery learning—including ethnoscience-infused variants—deepens conceptual understanding grounded in local culture and experience (Jannah & Atmojo, 2022). Innovations such as the flipped classroom nested within PBL further expand space for scientific exploration and classroom discourse (Madang et al., 2022).

Implementation in real classrooms, however, often encounters constraints of time for practical work, availability of equipment, and assessment design that together limit optimal hands-on science (Andayani & Madani, 2023; Fathorrozi & Muhith, 2021; Nurcahya et al., 2024). Digital technologies offer strategic responses: virtual laboratories, interactive simulations, data-loggers, and cloud-based collaborative platforms enable safe, flexible, and resource-efficient experimentation (Rana et al., 2023; Susanto et al., 2022; Syam & Kurniasih, 2023). Web-based assessment can deliver real-time feedback and capture process data, shifting KPS evaluation beyond end products toward comprehensive accounts of inquiry processes (Aldila et al., 2022).

Variations in school access to ICT and in teachers' digital competence are decisive for the quality of model implementation. Structured professional development is therefore essential to strengthen instructional design, technology integration, and process-oriented KPS assessment (Hasanah et al., 2023). Equally important, technology use must remain pedagogy-led: avoiding entertainment-driven distraction that displaces scientific reasoning, and cultivating critical digital literacy so students can select, evaluate, and present scientific information responsibly (Huda & Fatonah, 2023; Utami & Atmojo, 2021; Wati et al., 2023). When appropriately integrated, digital media have been shown to heighten motivation and enrich students' experiences in primary science (Hoerunnisa & Fauziah, 2023; Oktaviana & Ramadhani, 2023).

Cumulative evidence across inquiry, discovery, PBL/PJBL, and STEM—both with and without simulations/virtual labs—underscores the urgency of articulating their implications for strengthening KPS within the Merdeka Curriculum and the digital schooling ecosystem (Angelia et al., 2022; Artina et al., 2021; Azizah & Fauziah, 2023; Hasyim et al., 2021; Juni, 2021; Nahdi et al., 2020; Saputri, 2022). Accordingly, this article synthesizes theoretical foundations and empirical findings, identifies implementation challenges (time–tools–assessment–teacher readiness), and offers design recommendations for technology-supported KPS instruction and assessment that are adaptive, inclusive, and practice-oriented. The synthesis aims to serve as a conceptual and practical reference for teachers, schools, and policymakers seeking to optimize primary science learning in the digital era.

Method

Time and Location of the Research

This research was conducted during the second semester of the 2023/2024 academic year at two public elementary schools, namely SDN 010 and SDN 016 Tanjung pinang Timur, Riau Islands Province, Indonesia. These schools were selected because they actively implement science practicum-based learning and have begun integrating digital media in classroom instruction.

Type of Research

This study employed a qualitative research approach using a case study design. The case study approach was chosen to obtain an in-depth understanding of the implementation of science learning models, students' Science Process Skills (SPS), digital technology integration, and assessment practices in real classroom contexts (Creswell, 2015; Yin, 2018).

Research Subjects

The research subjects consisted of two Grade V science teachers and four Grade V students selected through purposive sampling. The selection criteria were based on active involvement in science learning activities and representation of varying levels of participation in classroom discussions and practicum sessions.

Research Stages

The research was carried out through the following stages: 1) Preliminary stage: literature review on science learning models, SPS, and digital-based science learning; development of observation and interview guidelines; 2) Data collection stage: classroom observations of science learning activities, semi-structured interviews with teachers and students, and documentation of learning tools, facilities, and instructional media; 3) Data validation stage: triangulation of data sources (observation, interview, and documentation) to ensure credibility; and 4) Data analysis and interpretation stage: systematic analysis and interpretation of findings to identify patterns and implications.

Data Collection Techniques

Data were collected using classroom observations, semi-structured interviews, and documentation. Observations focused on learning models, student engagement, and SPS indicators. Interviews explored teachers' instructional decisions and students' learning experiences, while documentation included lesson plans, worksheets, and digital learning media.

Data Analysis

Data were analyzed using an interactive analysis model consisting of data reduction, data display, and conclusion drawing and verification (Huberman, 2014). Data reduction involved selecting and coding relevant information related to learning models, SPS indicators, technology use, and assessment practices. Data were then organized in narrative and table forms to facilitate interpretation. Conclusions were drawn through iterative verification to ensure consistency and trustworthiness.

Result and Discussion

Implementation of Science Instructional Models in Grade V

Across both schools, Grade-V science lessons commonly combined small-group discussion with hands-on experimentation. Teachers reported that most Semester-1 topics were accompanied by a practicum task designed in advance, often coordinated across parallel classes to maintain alignment. One teacher described routine use of Project-Based Learning (PjBL) to model circulation through artefacts and flow charts pupils created. As Teacher Maya Aldapia (SDN 016, VA) noted, *"The science model we often use is group learning with discussion and experiments. Almost every science lesson includes an experiment in Semester 1, coordinated with the VB homeroom. We also used PjBL for the circulatory system to map the blood flow."*

Teachers perceived that practical work raised enthusiasm and on-task participation, even when it temporarily increased classroom noise. Teacher Tursami (SDN 016, VB) explained, *"We use group discussion and experiments. Students are very happy and active when we do experiments in science, even though the class gets noisy."* At SDN 010, three Grade-V teachers underscored cross-class coordination and a consistent emphasis on collaborative experimentation: *"The three of us coordinate to use the same model so there's no difference when teaching; the models we often use are group learning and experiments—recently on magnets."* —Sri Apriyani, Eli Yanti, Hanizar (SDN 010).

Table 1. Reported science teaching practices by teacher and school

School	Teacher	Group Discussion	Experiment/Practicum Frequency	PjBL Use	Cross-class Coordination	Noted Challenges
SDN 016	Maya Aldapia	Yes	Most topics (Sem. 1)	Yes (e.g., circulation)	Yes (VA–VB)	Need clearer practicum guide
SDN 016	Tursami	Yes	Frequent	Topic-specific	Yes	Managing noise during labs
SDN 010	Sri Apriyani	Yes	Frequent (e.g., magnets)	By topic	Yes (parallel classes)	Time to prepare materials
SDN 010	Eli Yanti	Yes	Frequent	By topic	Yes	Ensuring all pupils engage
SDN 010	Hanizar	Yes	Frequent	By topic	Yes	Differentiating tasks

A recurring operational challenge was the absence of a concise, indicator-based practicum guide that accommodates different learning styles. Without a common guide, some groups progressed unevenly and opportunities for prediction, inference, and synthesis were not always captured consistently during practical sessions.

The table 1 shows a convergent instructional pattern in which collaborative, experiment-rich lessons are the default across both schools. Coordination across parallel Grade-V classes appears to function as a fidelity mechanism: it synchronizes pacing, ensures similar exposure to practical tasks, and helps teachers share materials and troubleshoot common classroom issues (e.g., lab setup, time windows within a 35–40-minute period). PjBL surfaced most clearly in SDN 016 (Class VA) for complex topics such as circulation, suggesting that project modalities are selected when content benefits from model-building or multistep representations.

The cited challenges highlight implementation friction points rather than resistance to practical work. “Managing noise” reflects the tension between active learning and classroom control; teachers described strategic seating, role assignment within groups (leader, recorder, materials manager), and explicit time boxing to keep activity productive. Preparation time for materials (magnets, simple circuits, measurement tools) was another recurrent constraint, especially when classes run back-to-back and storage space is limited. The need for a concise practicum guide points to an equity issue: without shared, stepwise prompts, groups diverge in procedure quality, which can amplify differences in prediction and conclusion steps. In short, the pattern in Table 1 indicates strong cultural buy-in for practical science, with bottlenecks centered on logistics, differentiation, and the consistency of inquiry prompts.

Observed Science Process Skills (KPS) During Lessons

Classroom observations and interviews indicate that pupils performed strongly on basic KPS such as identifying tools and materials, carrying out procedures, and recording observations. In group work, pupils could discriminate functions of apparatus and complete measurement steps as instructed. Teacher Maya Aldapia (SDN 016) summarized, *“Science process skills in Grade V have developed; we guide pupils during practicums to apply the scientific method per their worksheets. For hypotheses we still use stories so they don’t think too abstractly. When drawing conclusions, pupils remain hesitant, and in presentations they need prompting to voice opinions or objections.”*

More advanced KPS—formulating hypotheses, making predictions, drawing conclusions, and communicating results—were less secure, largely due to confidence and language-production barriers. Teacher Tursami (SDN 016) observed, *“Children like and are enthusiastic each time we do experiments; they understand tools, materials, and steps. But when communicating in front of the class they are shy and afraid of being wrong, so many remain silent. We motivate them by awarding higher marks to pupils who present or rebut”*. At SDN 010, Sri Apriyanti and Hanizar added, *“We try to design simple experiments—like magnets. Students are happy and active, but when asked to present, we motivate them by promising a high score.”* Hanizar further reflected, *“We’ve provided support and motivation so pupils dare to present ideas, yet the same children tend to speak each time.”*

Pupils themselves articulated similar constraints. Mutiah (Grade VB) shared, *“I actually understand the point; I’m just confused about forming the sentences and afraid of being wrong.”* Choirul Anam (Grade VB) confessed, *“I’m embarrassed and afraid of making mistakes when giving an opinion or rebuttal during a friend’s presentation.”* Raihan added, *“In practicums I can differentiate tools and materials, but during discussions some friends go off-topic. For conclusions I’m still confused about wording—afraid of being wrong.”* A focused observation during a “light” unit confirmed this profile: observation, classification, and measurement were executed adequately in groups, while prediction, conclusion-writing, and oral communication required substantial prompting.

Table 2. Summary of Observed KPS Performance (Grade V)

KPS Indicator	Overall Performance	Typical Evidence from Classrooms
Observing	High	Accurate noting of visible changes; attention to apparatus use
Classifying	High	Sorting materials/tools by function and property
Measuring	Moderate–High	Following steps; units occasionally prompted by teacher
Predicting	Moderate	Requires cues; predictions often borrowed from examples
Hypothesis Formulation	Moderate	Story-based scaffolds needed to reduce abstraction
Concluding	Moderate–Low	Hesitancy synthesizing results; phrasing support required
Communicating/Presenting	Low–Moderate	Shyness/fear of error; few pupils dominate presentation

Table 2 reveals a split profile: pupils demonstrate procedural fluency with observable actions (seeing, sorting, measuring) yet show fragility in reasoning- and language-intensive moves (predicting, hypothesizing, concluding, presenting). Interviews and observations converge on affective factors (fear of error, shyness) and linguistic formulation demands (finding words to generalize from evidence) as the main impediments. Hypothesis-making improved when teachers anchored tasks in concrete stories or familiar contexts, which reduced abstraction and elicited more testable statements. Where units used structured sentence frames (“If… then… because…”) during predictions and conclusions, pupils produced more complete causal accounts, though this was not yet systematic.

The communication bottleneck also has a participation distribution dimension: a small subset of confident pupils often take the floor, while others defer. Teachers' practice of awarding bonus points for speaking successfully nudged participation, but unevenness persisted when prompts lacked targeted roles (e.g., designated evidence summarizer) or pre-presentation rehearsal (e.g., 30-second "pair share" before plenary). Finally, group discussions sometimes drifted off-task, especially between the measurement and conclusion stages, suggesting that transition prompts and time-boxed micro-milestones could stabilize the move from data to inference. Overall, the table points to a developmental sequencing need: keep the strong base in observation/classification/measurement while intentionally engineering language-rich moments for prediction, hypothesis, conclusion, and presentation.

Integration of Digital Technologies in Science Lessons

Both schools integrated basic digital media to support concept formation. At SDN 016, teachers reported using PowerPoint image prompts to spark curiosity and seed questions at lesson openings; at SDN 010, teachers described short YouTube clips to concretize abstract ideas prior to practical work and discussion. Because devices are limited and rotated, teachers typically pre-download selected videos and rely on a projector-laptop setup to ensure smooth delivery without network disruptions.

Teachers perceived digital media as helpful for visualizing invisible processes and maintaining engagement, while recognizing the need to balance screen-time with hands-on inquiry so that technology remains a scaffold rather than a distraction. Constraints included device rationing, preparation time to curate suitable clips, and the need for structured transitions from viewing to explaining, predicting, and concluding.

Table 3. Digital tools and patterns of use

Tool/Platform	Typical Use	Frequency	Perceived Benefit	Main Constraint
PowerPoint (images)	Advance organizers, prompts	Regular	Sparks curiosity; anchors discussion	Prep time for high-quality visuals
YouTube videos	Concretise abstract concepts	Regular	Dual-channel (audio-visual) support	Need to pre-download; clip curation
Projector + laptop	Whole-class display	Regular	Reliable delivery to all pupils	Hardware scheduling
Chromebooks	Small-group exploration	Rotational	Interactive tasks; content creation	Limited units; sharing logistics

The configuration in Table 3 indicates a whole-class first, small-group second media ecology. Lessons typically open with high-salience visuals (photos, schematics) to prime prior knowledge and elicit questions, followed by a brief video segment that animates invisible or time-compressed phenomena (e.g., magnetic field interactions, light reflection/refraction). Only after this do groups proceed to hands-on tasks, using the shared imagery and vocabulary as common reference points. This sequencing helps keep cognitive load manageable and ensures pupils possess shared mental models before manipulating apparatus.

Chromebooks extend possibilities for interactive exploration and artefact creation (short slideshows, labelled photos of setups), but scarcity requires rotation protocols; as a result, most pupils still experience digital content via whole-class projection. Teachers mitigate bandwidth and platform unpredictability by pre-downloading videos and preparing offline slide decks, which reduces downtime and preserves precious practical minutes. However, the reliance on teacher-managed displays means student-driven searching and data capture (e.g., micro-videos of experiments, digital lab notes) remain emergent rather than routine. The overall picture is a pragmatic adoption: technology is leveraged primarily to set up understanding and sustain attention, with gradual moves toward student production when devices are available.

Assessment Practices for Science Process Skills

Current assessment practices largely rely on module-provided sheets and group-level scoring. Indicator-level judgements (e.g., separate scores for prediction, hypothesis, conclusion, and communication) are not consistently recorded, and groups sometimes receive identical marks despite differing contributions. Teachers compensate informally by giving motivational points for oral contributions and providing immediate verbal feedback during demonstrations and presentations.

A need emerges for concise analytic rubrics aligned to KPS indicators, simple process logs for groups, and brief individual exit slips targeting language-heavy indicators. Such instruments would make growth visible, inform next-step teaching, and balance product- and process-oriented evidence.

Table 4. Status of KPS Assessment Components

Assessment Component	Status in Classrooms	Notes on Use
Indicator-based analytic rubric (observe→communicate)	Not systematic	Judgements often holistic at group level
Process log (group)	Partial	Observation notes exist; prediction/conclusion steps uneven
Individual checks (exit slips/mini-orals)	Limited	Used ad hoc for confidence-building
Real-time feedback (teacher)	Present	Verbal prompts during labs and presentations
Module worksheet scores	Present	Primary recorded evidence; may mask individual variance

Table 4 indicates that evidence capture is abundant but not sufficiently granular. Module worksheets ensure that most pupils submit a product, yet the lack of indicator-level scoring means teachers have limited visibility into specific KPS trajectories (e.g., a pupil improving in measurement precision but still struggling with causal explanation). Holistic group marks can obscure individual gains or misconceptions, especially in classes where a few confident speakers take on presentation roles. Process logs exist informally (teacher observation notes), but prediction and conclusion steps are the least consistently recorded, mirroring the performance weaknesses seen in Table 2.

Real-time verbal feedback is a strength of current practice; however, feedback without a parallel record is hard to aggregate into reports or to use for instructional planning across weeks. Light-touch tools—one-page analytic rubrics aligned to the seven indicators, brief exit slips focused on prediction/conclusion language frames, and a simple group process grid—would add minimal workload while sharpening validity and fairness. Such tools would also enable triangulation between product (worksheet), process (log), and performance (mini-oral), helping teachers target scaffolds (e.g., hypothesis sentence frames) to the exact indicators where pupils falter.

Discussion

The results show that Grade-V science in both schools foregrounds collaborative practical work and discussion, with emerging use of PjBL. This aligns with the positioning of Science Process Skills (KPS)—observing, classifying, measuring, predicting, concluding, designing experiments, and communicating—as central to twenty-first-century primary science and to the Merdeka's Curriculum project-based, contextual ethos (Aditiyas & Kuswanto, 2024; Wulandah et al., 2023). Prior work indicates that KPS-rich activities elevate not only academic outcomes but also learners' positive dispositions and self-regulation in everyday problem-solving (Fitri et al., 2020; Sinurat et al., 2023), which is consonant with teachers' reports of heightened enthusiasm during experiments.

The pattern of strong foundational KPS (observation, classification, measurement) alongside weaker language-intensive indicators (hypothesising, predicting, concluding, communicating) mirrors findings in studies where inquiry and problem-centered pedagogies require explicit scaffolds for reasoning and talk (Indah et al., 2023; Rahman et al., 2021). Evidence that PBL/PjBL and inquiry strengthen problem formulation, prediction, and data interpretation supports the current emphasis on practicum-rich lessons (Handayani et al., 2021; Wulandari & Oktaviani, 2024). Complementarily, discovery-oriented and ethnoscience-infused approaches have been shown to deepen conceptual understanding by anchoring explanations in familiar cultural contexts—an avenue that could further stabilise pupils' conclusion-writing (Jannah & Atmojo, 2022).

Resource and time constraints that limit practicum depth and assessment sophistication are well-documented in primary settings (Andayani & Madani, 2023; Fathorrozi & Muhith, 2021; Nurcahya et al., 2024). The schools' pragmatic use of PowerPoint prompts, YouTube clips, and rotating Chromebooks is consistent with research on technology as a lever for access and engagement when equipment is scarce. Virtual laboratories, interactive simulations, and data-loggers can complement existing practice by providing safe, repeatable experiments and richer data without heavy material outlays (Rana et al., 2023; Syam & Kurniasih, 2023). Web-based assessment environments can also capture process traces and deliver timely feedback—precisely the gap observed in current group-level grading (Aldila et al., 2022).

At the same time, the discussion results caution against letting media entertainment displace scientific reasoning. Prior studies show that carefully chosen digital media—comics, interactive apps, and video—improve attention and conceptual grasp when embedded in tasks that require explanation and argumentation (Hasanah et al., 2023; Kuway et al., 2023; Oktavia et al., 2021). Strengthening critical digital literacy and HOTS-oriented materials is therefore essential so that technology scaffolds hypothesising and concluding rather than merely illustrating content (Huda & Fatonah, 2023).

Teacher readiness emerges as a decisive factor. Evidence suggests that targeted professional development enhances teachers' capacity to design KPS-rich experiences and to integrate technology purposefully (Hasanah et al., 2023). In parallel, assessment research underscores the value of indicator-aligned instruments for observing KPS growth in primary grades (Aisah & Agustini, 2024; Darmaji et al., 2020). For the present context, succinct analytic rubrics, brief individual exit tasks for prediction and conclusion, and simple group process logs would translate the practicum energy already visible in classrooms into measurable, reportable learning progression.

Finally, the convergent literature on inquiry levels, guided discovery, and PBL corroborates the feasibility of raising pupils' higher-order KPS with structured scaffolding (Angelia et al., 2022; Artina et al., 2021; Hasyim et al., 2021; Nahdi et al., 2020). Reports that discovery learning reduces passivity (Juni, 2021) and that collaborative, active designs bolster science literacy (Septi et al., 2022) align with teachers' observations of motivation during experiments. Moving forward, coupling these designs with technology-mediated rehearsal spaces (e.g., short rehearsal recordings for presentations) and indicator-based assessment will likely address the specific bottlenecks identified—namely, predicting, concluding, and communicating—within the realities of time and resource constraints (Azizah & Fauziah, 2023; Saputri, 2022).

Conclusion

This study concludes that Grade V science learning in public elementary schools in the digital era is predominantly characterized by collaborative discussion and hands-on experimentation, with emerging application of project-based learning. These approaches effectively support foundational Science Process Skills (observing, classifying, and measuring), yet higher-order and language-intensive skills—predicting, formulating hypotheses, concluding, and communicating—remain underdeveloped due to students' limited confidence, linguistic challenges, and the predominance of product-oriented, group-based assessment. The integration of digital media contributes positively to conceptual understanding and student engagement, although its impact is constrained by limited device availability and instructional preparation time. These findings suggest that strengthening students' science process skills requires pedagogy-led technology integration, explicit scaffolding for scientific reasoning and communication, and indicator-based assessment aligned with inquiry processes. Practically, teachers are encouraged to employ concise analytic rubrics, structured process logs, and brief individual tasks to capture students' reasoning more accurately and equitably. This study is limited by its small sample size and qualitative scope; therefore, future research is recommended to employ mixed-methods or experimental designs with broader samples to examine the effectiveness of specific learning models and digital tools in improving higher-order science process skills across diverse elementary school contexts.

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Author Contributions

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Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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