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Development of E-Student Worksheet Based on Problem-Based Learning Model Using Liveworksheet Platform to Improve Students' Critical Thinking Skills

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Abstract – Physics education in the 21st century must be directed toward developing higher-order and process-oriented skills that enable students to think critically and engage in scientific inquiry. Traditional instructional practices often emphasize memorization, leaving limited opportunities for students to cultivate critical thinking skills (CTS) and science process skills (SPS), particularly in abstract topics such as sound waves. This research was conducted to develop and evaluate a problem-based learning (PBL) model assisted by live worksheets to enhance students' CTS and SPS. The study employed a research and development design based on the ADDIE model, which consisted of the stages of analysis, design, development, implementation, and evaluation. Thirty-five grade XI students at a public senior high school in Makassar participated in the implementation. Data were obtained through expert validation, a CTS test, SPS observation sheets, and student response questionnaires. Expert validation results indicated that the product was in the very valid category, with average scores above 85%, while student responses placed the worksheets in the practical category, with averages exceeding 80%. Statistical analysis of CTS using pretest-posttest measures showed significant improvement, with normalized gain (N-Gain) scores categorized as medium. Observations further confirmed that students' SPS, such as hypothesizing, experimenting, and interpreting results, improved substantially during the learning process. The novelty of this study lies in positioning live worksheets as a central scaffold within PBL cycles, directly guiding inquiry and reasoning rather than serving as supplementary material. The findings conclude that the developed PBL-assisted live worksheets are valid, practical, and effective, contributing to advances in physics education by strengthening both critical thinking and science process skills.

Keywords: critical thinking skills; liveworksheets platform; physics education; problem-based learning; sound waves

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I. INTRODUCTION

In the 21st century, education is expected to equip students with the capacity to think critically, solve problems, and apply knowledge in authentic contexts. Physics, as a central discipline within science, not only provides conceptual knowledge but also develops skills that are essential for lifelong learning. Tindowen et al. (2017) emphasized that contemporary learning

must move beyond traditional methods and embrace approaches that strengthen student competencies in inquiry, analysis, and problem-solving. In line with this, [Hidayatullah et al. \(2018\)](#) highlighted the necessity for learning innovations that can foster scientific literacy and promote active engagement. The challenges of modern science education demand that learning is not only focused on the mastery of concepts but also on preparing students to function as active problem solvers in dynamic social and technological environments.

Global and national educational reforms have consistently called for approaches that integrate student-centered learning with digital innovations. Argue that digitalization in education has created opportunities for interactive learning environments that can adapt to diverse student needs. Similarly, [Susilawati et al. \(2020\)](#) point out that learning models should not merely transfer knowledge but also encourage creativity and critical thinking through contextual and technology-supported learning. Within this framework, physics learning must be designed to ensure that students can connect abstract concepts with real-world applications while also developing science process skills. The integration of digital worksheets, interactive platforms, and inquiry-based models is therefore viewed as a promising response to these demands.

One of the persistent problems in physics learning is the low mastery of science process skills and conceptual understanding among students. [Rahmmawati and Asri \(2023\)](#) noted that physics is often perceived as difficult because of its abstract concepts, while [Wahyunita and Subroto \(2021\)](#) further emphasized that the limited use of innovative learning models contributes to students' difficulties. This is particularly evident in topics such as sound waves, which require students to visualize and analyze invisible phenomena. As a result, students often fail to apply theoretical knowledge to practical contexts, which hampers the development of both understanding and competence.

To overcome these challenges, researchers have recommended student-centered models that encourage active participation and problem-solving. [Sari et al. \(2022\)](#), [Septiana et al. \(2023\)](#), and [Tong et al. \(2025\)](#) documented that problem-based learning (PBL) is an effective approach to enhance student motivation, develop inquiry skills, and improve learning outcomes. [Jiang et al. \(2025\)](#) also confirmed that digital learning platforms combined with problem-solving tasks could enhance conceptual mastery while simultaneously fostering independence. These findings suggest that combining inquiry-based strategies with technology-supported tools can address persistent problems in physics education and support the development of essential scientific skills.

Problem-based learning has been widely recognized as an effective pedagogical approach to support active learning. [Argaw et al. \(2017\)](#) demonstrated that PBL improves students' higher-order thinking and conceptual mastery, while [Husnah \(2018\)](#) emphasized its role in fostering collaborative learning environments. When integrated with digital platforms, the potential of PBL

becomes even greater. For instance, [Sari et al. \(2022\)](#) showed that combining PBL with electronic worksheets enhanced student participation and provided opportunities for inquiry-driven activities. [Ilana and Cintamulya \(2022\)](#) further highlighted that e-worksheets encourage students to engage with scientific content more interactively, while [Poveda \(2022\)](#) pointed out that they also allow teachers to monitor student progress more effectively. Together, these studies indicate that the integration of PBL and digital worksheets has the potential to transform the learning of abstract physics concepts into meaningful and measurable experiences.

Recent empirical studies provide evidence that interactive worksheets and online platforms can significantly enhance student motivation and achievement. [Elissa et al. \(2020\)](#) found that students using digital worksheets demonstrated higher levels of engagement, while [Sugandi et al. \(2024\)](#) reported that such tools improved conceptual understanding across science subjects. Similarly, [Tiara et al. \(2023\)](#) noted that integrating worksheets into digital platforms provided more flexible and accessible learning opportunities. However, despite these promising results, [Septiana et al. \(2023\)](#) argued that many of these interventions remain general and do not specifically address the development of science process skills. Moreover, [Asshidiq et al. \(2023\)](#) and [Puriasih and Rati \(2022\)](#) both found that while e-worksheets are effective for supporting conceptual learning, research explicitly focusing on their integration with PBL in physics topics such as sound waves remains scarce.

The literature also points to the limited attention given to the systematic evaluation of digital worksheet-based PBL models. [Sumanik \(2022\)](#) observed that many studies emphasize conceptual mastery but rarely provide comprehensive assessments of students' science process skills. [Sari et al. \(2019\)](#) similarly noted that while PBL has been shown to improve student understanding, the integration of electronic student worksheets as a core component has not been consistently examined. [Aiyesi and Prasetyo \(2025\)](#) and [Sahara et al. \(2020\)](#) added that while digitalization has advanced rapidly in education, empirical evidence on its impact on specific physics topics is still developing. [Saputri et al. \(2025\)](#) emphasized that the effectiveness of digital worksheet integration needs to be validated through robust experimental designs, particularly in contexts where students' access to technology and digital literacy may vary significantly. These findings collectively highlight a research gap that calls for systematic exploration of PBL integrated with electronic student worksheets on physics topics such as sound waves.

Based on the identified gap, this study aims to develop and evaluate a PBL model using live worksheets as electronic student resources to enhance science process skills and learning outcomes on the topic of sound waves. By employing a quasi-experimental design, the research seeks to generate empirical evidence on the effectiveness of integrating PBL with interactive digital worksheets. The study not only examines conceptual mastery but also systematically

evaluates science process skills, which are often overlooked in previous research. The novelty of this study lies in its dual contribution: first, in positioning live worksheets not as supplementary materials but as integral scaffolding within the PBL cycle; and second, in focusing on sound waves, a topic that poses unique conceptual and experimental challenges for high school students.

II. METHODS

This research applied a Research and Development (R&D) design to produce and test a PBL model assisted by live worksheets, aiming to enhance students' SPS and CTS. The R&D approach was chosen because it allows for systematic steps in developing, validating, implementing, and evaluating an educational product to ensure its validity, practicality, and effectiveness (Sugiyono, 2015). To guide the development process, this study adopted the ADDIE model: Analysis, Design, Development, Implementation, and Evaluation, which has been widely recognized for structuring instructional product development (Branch, 2009; Hidayat & Nizar, 2021). The sequential steps of the research and development process are illustrated in Figure 1.

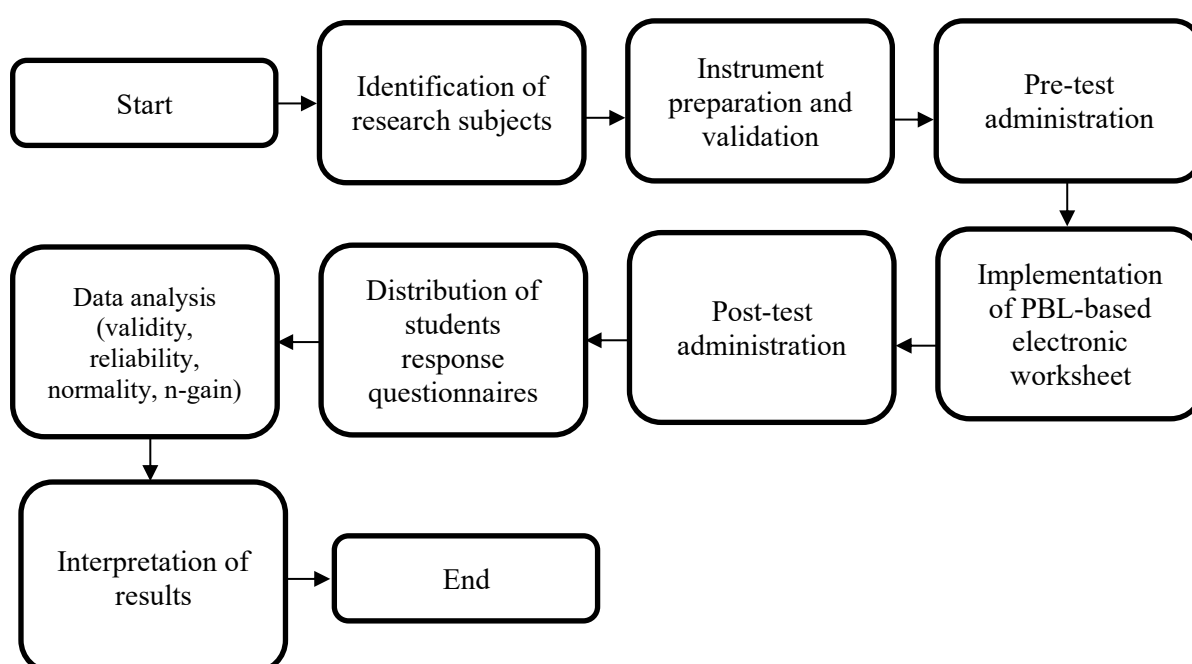


Figure 1. Research and development procedures using the ADDIE Model

The study was conducted in a public senior high school in Makassar, involving 35 students from class XI as research participants. The participants were selected based on contextual needs identified by the teacher, and the intervention was implemented in the classroom setting. Ethical approval and permission were obtained from the school, and participants provided informed consent.

In the analysis phase, preliminary observations and teacher interviews revealed that students experienced difficulties in understanding the abstract concepts of sound waves. These findings formed the basis for designing learning materials that could better connect theory with real-life applications. The design phase translated the analysis into the structure of electronic student worksheets (E-SWs) built through the Live worksheets' platform, integrating features that allowed for interactive tasks, contextual problems, and problem-solving activities aligned with PBL principles.

The development phase produced prototype worksheets that were subjected to expert validation. Three validators, along with content, language, and media experts, assessed the quality of the worksheets based on accuracy, clarity, design, and functionality. The validation scores were averaged, and the results are presented in Table 1.

Table 1. Results of expert validation of the developed worksheets

No.	Validator	Average	Criteria
1.	Material expert validation I	83.25%	Very valid
2.	Material expert validation II	96.86%	Very valid
Overall average		90.06%	Very valid
3.	Media expert validation I	86.25%	Very valid
4.	Media expert validation II	92.30%	Very valid
Overall average		89.28%	Very valid
5.	Practitioner expert validation (physics teacher)	96.25%	Very valid

As shown in Table 1, the mean validation scores from all experts exceeded 96.9%, placing the product in the “very valid” category. This demonstrates that the worksheets fulfilled the necessary quality standards. Minor revisions were incorporated in response to expert feedback, such as refining the clarity of instructions and improving visual layout, before the worksheets were applied in the classroom.

During the implementation phase, the validated worksheets were integrated into PBL learning cycles. Students were divided into small groups to analyze contextual problems, develop hypotheses, collect information, conduct experiments, and present their findings. The role of the teacher was as a facilitator, guiding the process and ensuring that students engaged meaningfully with the live worksheet activities. The platform functioned not only as a learning medium but also as an interactive assessment tool, providing immediate feedback and enabling teachers to monitor progress.

The evaluation phase focused on measuring both SPS and critical thinking skills. SPS were assessed using observation sheets aligned with indicators such as hypothesizing, experimenting, and interpreting results. Given that SPS were primarily observable during learning activities, a

non-equivalent post-test-only control group design was applied (Fraenkel & Wallen, 2012). In contrast, critical thinking skills were measured through a pretest–posttest design, allowing for the calculation of normalized gain (N-Gain) to categorize improvements (Hake, 1998). To ensure the robustness of the instruments, validity was established through expert review, and reliability was tested using Cronbach’s alpha. The coefficients obtained exceeded 0.70, which indicates a high level of internal consistency (Arikunto, 2013; Akdon & Riduwan, 2012). These procedures guaranteed that the instruments were appropriate for measuring the intended variables.

III. RESULTS AND DISCUSSION

The results of this research are presented in the order of the development process and subsequent testing of the PBL-assisted liveworksheets. The first stage involved expert validation, which was carried out by three specialists in content, language, and media. The outcomes of this stage are summarized in Table 1, showing that the mean validation scores across all aspects exceeded 92%. These values place the product in the “very valid” category, indicating that the developed worksheets fulfilled the expected criteria of accuracy, clarity, and design feasibility. The expert feedback suggested only minor revisions, such as refining instruction wording and adjusting layout consistency, which were subsequently incorporated into the product. This strong validation provided the foundation for the next stage of development.

Following validation, the product was refined and further developed into its final version using the live worksheets platform. The electronic student worksheets were designed to align with the steps of problem-based learning, integrating contextual problems, inquiry activities, and interactive feedback. The finalized product is illustrated in figures 2–4, which depict examples of the interface, problem prompts, and interactive features of the worksheets. These figures demonstrate the alignment between the PBL framework and the affordances of live worksheets, particularly in enabling students to engage with real-world contexts while receiving immediate digital feedback.



Figure 2. Initial cover and introduction

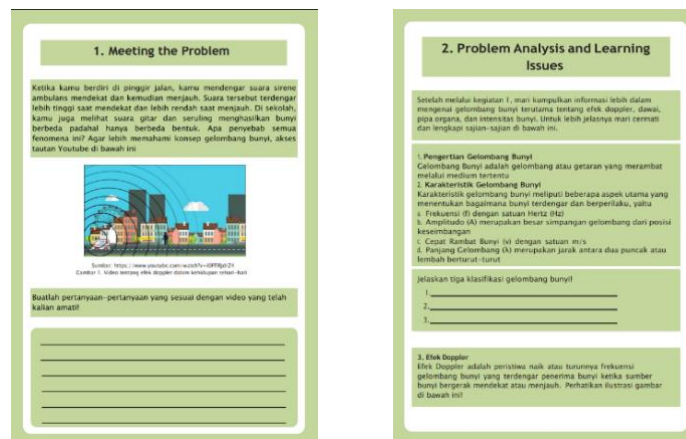


Figure 3. Display of materials and exercises

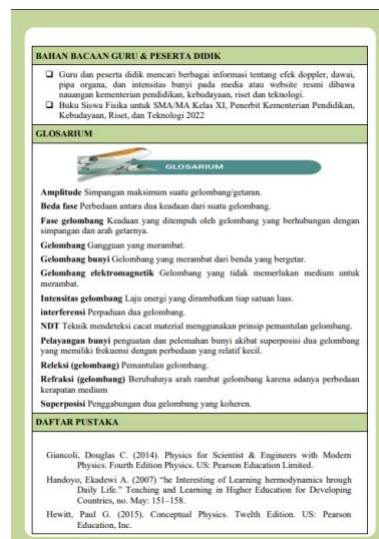


Figure 4. Final view of the PBL-Assisted liveworksheets

The practicality of the product was evaluated through student response questionnaires administered after classroom implementation. As shown in Table 2, the average student response exceeded 80%, placing the product in the “practical” category. Students reported that the worksheets were engaging, easy to use, and supportive of collaborative problem-solving. This positive feedback corroborates the expert validation results, suggesting that the product was not only theoretically sound but also appealing and usable in practice.

Table 2. Student responses to the PBL-assisted live worksheets

Aspect	Average (%)	Category
Content	79.4	Practical
Appearance and design	79.4	Practical
Ease of use	81	Practical

The effectiveness of the developed product was measured through critical thinking skills. Pretest and post-test scores of student achievement on the sound wave topic are presented in Table 3, with the mean score increasing from 71% in the pretest to 84% in the post-test. The paired-sample t-test analysis confirmed that this improvement was statistically significant, with $t(34) = -11.582, p < 0.05$. In addition, the normalized gain (N-Gain) was 0.47, which falls in the medium category, indicating that the intervention substantially improved student understanding.

Table 3. Descriptive statistics and t-test results for students’ critical thinking skills

CTS Indicators	Pretest	Posttest	N-gain	Category
Analyzing facts	72%	86%	0.48	Medium
Formulating	76%	86%	0.41	Medium
Providing arguments	64%	83%	0.52	Medium
Making conclusions	72%	81%	0.46	Medium
Average	71%	84%	0.47	Medium

Observation of students’ SPS during classroom implementation showed marked improvement across key indicators, including hypothesis formulation, experimentation, and interpretation of results. Students were increasingly able to articulate predictions, conduct experiments systematically, and draw reasoned conclusions. These improvements were consistent with their reported experiences, as many students indicated that the worksheets guided them in applying scientific reasoning and working collaboratively.

The present study set out to develop and evaluate a PBL model assisted by live worksheets, aiming to strengthen students’ SPS and improve achievement on the sound wave topic. The overall pattern of findings, with very high expert validation, positive student responses, and statistically significant learning gains, aligns with contemporary expectations that physics

instruction should cultivate active, inquiry-oriented competencies while leveraging digital media to support personalization and engagement (Tindowen et al., 2017; Hidayatullah et al., 2018; Susilawati et al., 2020). Within this competency-based vision, the intervention's design choices align with calls to place abstract content in meaningful problem contexts, enabling learners to connect representations, data, and claims during guided inquiry.

Product quality, as evidenced by expert appraisal across content, language, and media, exceeded the conventional acceptance threshold and indicates that the instructional artefacts meet criteria for accuracy, clarity, and usability. Such outcomes are expected when development follows a systematic R&D pathway and a structured design framework like ADDIE, which together emphasize iterative specification, prototyping, and review before implementation (Sugiyono, 2015; Branch, 2009; Borg & Gall, 2003). The validators' minor recommendations, principally about wording precision and layout consistency, were incorporated before classroom use, strengthening fidelity and ensuring that any observed learning effects are not confounded by avoidable design flaws.

Practicality data from learners further substantiate the product's classroom readiness. Students' positive ratings (>80%) are consistent with evidence that electronic worksheets can heighten engagement through interactivity, immediate feedback, and clearer task structuring (Ilana & Cintamulya, 2022; Poveda, 2022; Elissa et al., 2020). Studies on digital worksheet ecosystems similarly report gains in motivation and conceptual access when content is chunked into navigable steps and feedback loops are explicit (Ariskasari & Sulisworo, 2021; Sugandi et al., 2024; Tiara et al., 2023). In our context, live worksheets allowed teachers to monitor progress in real time while students collaborated on problem prompts grounded in everyday acoustical phenomena. This affordance coheres with broader trends in technology-supported formative assessment (Susilawati et al., 2020).

Effectiveness results show a clear pre- to post-test improvement (from 71 to 84) with a significant paired t-test and a normalized gain of 0.47, which falls in the medium category according to established interpretive bands (Hake, 1998). This magnitude is comparable to effects typically observed when learners transition from expository routines to structured inquiry with problem framing, hypothesis generation, and evidence-based explanation (Sari et al., 2022; Septiana et al., 2023; Tong et al., 2025). It is also consonant with reports that coupling PBL cycles to digital scaffolds can amplify conceptual restructuring by making intermediate reasoning products (assumptions, representations, partial solutions) visible and revisable (Amin et al., 2020; Jiang et al., 2025; Nasution, 2021). Within the PBL literature, the gains we document mirror findings that authentic problems catalyze higher-order thinking and transfer, particularly when

collaboration and metacognitive reflection are planned into the sequence of activities ([Argaw et al., 2017](#); [Husnah, 2018](#)).

Improvements in SPS observed during implementation reinforce the claim that the intervention targeted not only declarative knowledge but also procedural and epistemic practices. Students advanced in articulating testable predictions, designing simple investigations, and interpreting patterns—abilities central to the aims articulated in prior work recommending inquiry-aligned task environments ([Sari et al., 2022](#); [Septiana et al., 2023](#)). Notably, earlier studies on e-worksheets often concentrated on conceptual outcomes and motivation; fewer explicitly tracked SPS indicators across lessons ([Asshidiq et al., 2023](#); [Puriasih & Rati, 2022](#)). By embedding observation-based SPS measures within classroom enactment, this study addresses the methodological gap and demonstrates that digital worksheets, when tightly integrated with PBL routines, can support growth in process-oriented competencies rather than merely enhancing answer accuracy.

The product features showcased in Figures 2–4, contextual problem prompts, staged inquiry guides, and instant feedback appear to be the proximal mechanisms behind these gains. Such features translate PBL principles into concrete learner actions, lowering extraneous load while maintaining the desirable difficulties that drive conceptual change. This alignment is important in domains like wave physics, where invisible properties (frequency, wavelength, phase) must be coordinated across symbolic, graphical, and experiential representations. Prior analyses emphasize that digitalization in the classroom must move beyond content delivery to orchestrate rich task designs and traceable learning processes; our implementation illustrates this shift on a topic known for representational challenges ([Aiyesi & Prasetyo, 2025](#); [Sahara et al., 2020](#); [Saputri et al., 2025](#)).

At a broader level, the findings resonate with curricular expectations that physics learning cultivates inquiry dispositions alongside conceptual mastery ([Tindowen et al., 2017](#); [Hidayatullah et al., 2018](#)). The results add nuance to earlier demonstrations of digital worksheet efficacy by showing that when such tools are embedded as integral scaffolds rather than as add-ons, students' reasoning becomes more explicit and collaborative, and teacher orchestration gains real-time diagnostic visibility ([Elissa et al., 2020](#); [Sugandi et al., 2024](#); [Tiara et al., 2023](#); [Poveda, 2022](#)). In this regard, the present study provides a concrete instantiation of the design stance proposed in the reviewed literature: technology should structure the problem space, surface intermediate thinking, and facilitate feedback cycles ([Susilawati et al., 2020](#)).

Nonetheless, two considerations temper the interpretation of impact. First, while the medium N-Gain indicates meaningful improvement, it also signals room for strengthening the problem sequences, particularly in tasks that demand multi-representation coordination. Iterative

refinement cycles typical of R&D research guided by structured evaluation frameworks are therefore warranted to calibrate difficulty and deepen transfer opportunities (Sugiyono, 2015; Borg & Gall, 2003; Branch, 2009). Second, the quasi-experimental structure and class-bounded implementation limit claims about generalizability and internal validity; future studies should broaden samples, include comparison conditions with matched task time, and extend SPS tracking across units to test durability (Fraenkel & Wallen, 2012; Sumanik, 2022; Sari et al., 2019). These are not defects of the present design but typical constraints at this stage of product maturation in educational contexts.

IV. CONCLUSION AND SUGGESTION

This study developed and evaluated a PBL model assisted by live worksheets on the topic of sound waves. The results indicated that the product fulfilled the criteria of validity and practicality, with expert validation scores placing the worksheets in the very valid category and student responses showing them to be practical and engaging. Statistical and observational evidence confirmed that the model effectively enhanced students' critical thinking skills and science process skills. Learners demonstrated increased ability to reason, hypothesize, conduct experiments, and interpret data during classroom implementation. These findings establish that integrating live worksheets within a PBL framework provides a valid and effective strategy for fostering essential higher-order and process-oriented skills in physics learning.

Despite these promising outcomes, the study has several limitations. The quasi-experimental design and relatively small sample size restrict the generalizability of the findings, while the focus on a single physics topic limits the scope of application. Future research should expand the implementation to larger and more diverse populations, incorporate comparative groups across different instructional models, and extend the assessment of science process skills over longer instructional units. Furthermore, refinement of the worksheet design to address more complex representational challenges may enhance its effectiveness. Nevertheless, this study contributes to the field of physics education by providing empirical evidence that technology-supported PBL models, specifically through the integration of live worksheets, can serve as powerful tools to foster student engagement, conceptual understanding, and scientific reasoning.

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