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Experience Learning Cycle-Based Classroom Management: Prophetic Integrated PhET Virtual Labs to Enhance Students' Understanding of Wave Concepts

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Abstract – *Wave concepts in physics are inherently abstract and often lead to misconceptions, especially when virtual laboratory activities are implemented without structured classroom management and guided reflection. Additionally, virtual science learning is frequently focused mainly on cognitive outcomes, while character development, particularly integrity in scientific practice, receives less systematic attention. This study addressed this gap by developing and evaluating a classroom management guide for Virtual Science Labs (PhET Simulations) based on the Experiential Learning Cycle (ELC) and integrated with prophetic values to enhance university students' understanding of wave phenomena while fostering character development. Using a Research and Development (R&D) approach with the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), the study involved 14 fifth-semester students from the Physics Education Study Program at Universitas Muhammadiyah Prof. Dr. HAMKA in the 2024–2025 academic year. Data were collected through expert validation sheets, wave conceptual understanding tests (pre-test and post-test), and prophetic character observation sheets. Expert validation indicated that the guide was highly feasible, with a mean score of 3.67 (87.5%) for content validation and 3.33 (83.3%) for media validation. Effectiveness results showed significant improvement in conceptual understanding, with scores increasing from 42.50 (pre-test) to 85.40 (post-test) and an N-gain of 0.75 (high category). Observations also suggested successful enactment of prophetic values during PhET-based practicums, particularly Sidiq (90%) and Amanah (85%), reflected in honest data recording and responsible task completion. The novelty of this study lies in the systematic integration of ELC-based classroom management, interactive PhET visualization, and the operationalization of prophetic values within a single instructional product. Overall, the developed model is feasible and effective for supporting both conceptual learning and character development focused on integrity in wave instruction, offering a comprehensive contribution to higher-education physics education.*

Keywords: *experiential learning cycle; PhET simulation; physics education; prophetic values; wave concepts*

I. INTRODUCTION

Higher education in science during the era of Industry 4.0 and Society 5.0 requires a pedagogical shift that moves beyond simple knowledge transfer to include the development of digital literacy and character. Education acts as a catalyst for national progress (Habsy et al., 2024). In physics education at the university level, students are expected not only to apply mathematical formulas but also to gain deep, meaningful concepts. As a core science, physics explains natural phenomena, drives technological innovation, and solves real-world problems (Smye, 2018). This evolution in teaching methods emphasizes the importance of innovative strategies to prepare students for the demands of the modern technological society, fostering essential skills and holistic understanding.

Wave concepts form a fundamental yet abstract part of physics because they require mathematical modeling, spatial visualization, and the linking of theory with observable phenomena. Based on initial observations and a preliminary study involving fifth-semester physics students at Universitas Muhammadiyah Prof Dr HAMKA, several learning challenges were identified. Pre-test results showed only 35% of students achieved passing scores on standing-wave and interference topics. Questionnaires revealed that 65% of students struggled to visualize wave phases and connect variables when learning relied on text or static images. Classroom instruction also remained mainly instructor-centered, limiting student independence during experiments. As a result, some students were less honest in reporting practicum data, trying to match results with textbook expectations. These conditions align with ongoing misconceptions in wave learning, such as misunderstandings of the relationships between frequency, wavelength, and wave speed, as well as difficulties interpreting graphs and simulations (Barniol & Zavala, 2016; Omar, 2023).

Representing wave phenomena such as interference, diffraction, and superposition through traditional explanations or lectures alone is challenging. Conventional labs also face limitations in providing dynamic, manipulable visualizations due to time and equipment constraints. These issues can perpetuate misconceptions among students. Therefore, digital tools, especially virtual laboratories, have emerged as promising alternatives to enhance visualization and conceptual change. PhET Virtual Labs/Simulations (Physics Education Technology Simulations) offer interactive experiences that make understanding physics concepts more accessible (Canright & Brahmia, 2024; Darwis et al., 2023; Korlat et al., 2024; Xi, 2024). These simulations are freely available for educators and students through the official platform (Vogt et al., 2023). Previous studies indicate that PhET simulations can improve understanding and student engagement compared to traditional methods (Banda & Nzabahimana, 2021; Banda & Nzabahimana, 2023).

However, when classroom management isn't well-structured, PhET usage often reduces to demonstrations, limiting students' chances for reflection and meaning-making (Banda & Nzabahimana, 2021; Hu et al., 2025).

To enable meaningful learning, appropriate instructional models are necessary to guide students from experience to understanding and application. The Experiential Learning Cycle (ELC) views learning as a repeating process of concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984). Research shows that experiential learning–based teaching can enhance conceptual understanding, critical thinking, and engagement in science (Morris, 2020). Beyond cognitive gains, today's education also faces challenges related to integrity. Science learning should incorporate values rooted in theology and humanitarian principles. Integrating prophetic values, *Sidiq* (honesty in data reporting), *Amanah* (responsibility in tasks), *Tabligh* (scientific communication), and *Fatonah* (solution-oriented intelligence), aims to develop students with both academic competence and moral character. These values are vital for shaping holistic scientists who demonstrate honesty, responsibility, collaboration, and respect for nature's order. Studies emphasize the incorporation of values and character education into science to maintain ethics and spirituality in scientific development (Brown et al., 2023; Aulia et al., 2022). However, research explicitly embedding prophetic values into technology-based physics learning, especially in virtual labs, remains limited.

Although many studies have explored simulation-based physics learning, limited research has combined structured experiential pedagogy with explicit internalization of character values within virtual laboratory environments. Therefore, this study aims to assess the effectiveness of integrating the ELC with PhET virtual simulations and the internalization of prophetic values (*Sidiq, Amanah, Tabligh*, and *Fatonah*) in enhancing university students' conceptual understanding of wave phenomena, engagement, and scientific integrity. The novelty of this research lies in its comprehensive instructional framework that systematically merges three interconnected dimensions: structured classroom management guided by ELC to transition students from concrete experience to abstract conceptualization, intentional use of PhET simulations as interactive tools for exploration rather than just demonstrations, and clear integration of prophetic values within each learning phase to promote honesty in data reporting, responsibility in experimentation, effective scientific communication, and problem-solving skills.

II. METHODS

This study employed a Research and Development (R&D) approach using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). ADDIE was selected because it provides a systematic yet flexible framework for developing instructional products and evaluating them through staged procedures (Branch, 2010; Molenda, 2015). The product developed was a classroom management guide for Virtual Science Labs based on the ELC, integrated with prophetic values *Sidiq*, *Amanah*, *Tabligh*, and *Fatonah* for wave-related topics using PhET Simulations.

The participants consisted of 14 fifth-semester students from the Physics Education Study Program at Universitas Muhammadiyah Prof. Dr. Hamka in the 2024–2025 academic year. Participants were selected through purposive sampling based on two criteria: (1) they had completed foundational physics courses and (2) they had prior exposure to virtual laboratory environments, which supported the feasibility of implementing PhET-based learning activities in the Wave Physics course context.

The product development process followed the five ADDIE stages, as summarized in Figure 1. In the analysis stage, a needs assessment was conducted through curriculum review, analysis of student characteristics, and identification of learning difficulties related to abstract wave concepts. At this stage, the rationale for using PhET virtual laboratories as visual–interactive learning media was established, and the relevance of integrating prophetic values into physics learning was examined (Banda & Nzabahimana, 2021; Banda & Nzabahimana, 2023). The outputs of this stage served as the basis for the instructional and character-integration specifications used in subsequent stages.

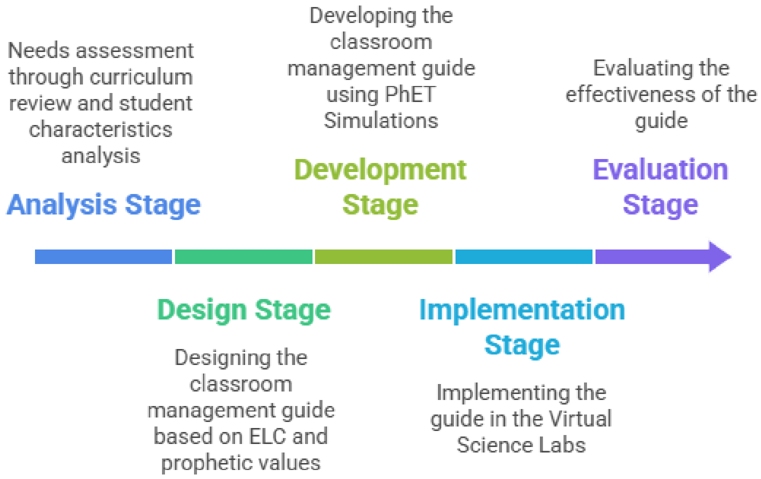

Figure 1. Stages of the ADDIE model applied in this study

Furthermore, the design stage focused on developing a classroom management model grounded in the ELC, which comprises concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984). Each ELC stage was aligned with targeted PhET simulation activities and integrated with prophetic values grounded in humanization, liberation, and transcendence as discussed in prophetic social science scholarship (Wulansari & Khotimah, 2019). Instructional materials and assessment instruments to measure students' conceptual understanding of wave topics were also designed at this stage. Then, the development stage produced the initial product: a classroom management guide, PhET virtual lab–based learning scenarios, and instruments for evaluating conceptual understanding. The developed products were then validated by subject-matter and instructional design experts to assess content and construct validity, as well as linguistic clarity. Expert validation is a central component of R&D to ensure product quality prior to implementation (Branch, 2010).

The implementation stage involved applying the developed product in a Wave Physics course. The trial was conducted in a single class using a pre-test and post-test design to assess improvements in students' conceptual understanding of wave concepts. During implementation, learning observations were conducted, and students' responses to the use of PhET simulations and the integration of prophetic values were collected. Last, the evaluation was conducted through formative and summative processes. Formative evaluation was used to refine the product at each ADDIE phase, while summative evaluation assessed the product's effectiveness in improving students' conceptual understanding of wave concepts. Product effectiveness was analyzed using the normalized gain (N-gain) score, which is commonly used to measure conceptual improvement in physics education (Coletta & Steinert, 2020; Menchafou, 2023).

The study used three main instruments: (1) expert validation sheets to assess the feasibility of content, media, and prophetic value integration; (2) wave concept understanding tests (pre-test and post-test) to measure conceptual improvement; and (3) prophetic character observation sheets to evaluate the enactment of *Sidiq, Amanah, Tabligh*, and *Fatonah* during PhET-based learning activities. Data were collected through: (1) expert validation of the developed product, (2) administration of conceptual understanding tests before and after implementation, and (3) direct classroom observations during virtual laboratory learning to examine the development of students' prophetic character. Expert validation data were analyzed using a five-point Likert scale. Mean scores were converted into feasibility percentages to determine product feasibility levels. The conversion and category interpretation followed the criteria in Table 1 (Sugiyono, 2019).

Table 1. Likert-scale criteria for product feasibility based on mean score and feasibility percentage

Mean score range	Feasibility percentage	Feasibility category
4.21 – 5.00	81% – 100%	Highly feasible
3.41 – 4.20	61% – 80%	Feasible
2.61 – 3.40	41% – 60%	Moderately feasible
1.81 – 2.60	21% – 40%	Less feasible

Improvements in conceptual understanding were analyzed using N-gain calculated from pre-test and post-test scores. N-gain indicates the effectiveness of the instructional intervention in improving conceptual understanding (Coletta & Steinert, 2020). The N-gain computation is presented in Equation (1):

$$\text{N-gain} = \frac{\text{Post-test score} - \text{Pre-test score}}{\text{Maximum score} - \text{Pre-test score}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The resulting N-gain values indicate the proportion of possible improvement achieved after the intervention. The classification of N-gain into high, moderate, and low improvement levels followed the criteria in Table 2.

Table 2. N-Gain classification used to interpret students' conceptual understanding improvement

Gain score	Categori
$(g \geq 7.0)$	High
$(0.30 \leq g < 0.70)$	Moderate
$(g < 0.30)$	Low

Prophetic character was analyzed using descriptive quantitative procedures based on observational data addressing indicators associated with *Sidiq, Amanah, Tabligh*, and *Fatonah*. Scores from the observation rubric were converted into percentage achievement levels. The interpretation of these percentages followed the achievement categories shown in Table 3 (Brown et al., 2023; Kementerian Pendidikan dan Kebudayaan Republik Indonesia, 2018; Wulansari & Khotimah, 2019). The percentage-based categories in Table 3 were applied to summarize the level of prophetic character attainment during PhET-based practicum sessions

Table 3. Percentage-based categories for interpreting students' prophetic character achievement

Percentage range	Achievement category
81% – 100%	Highly feasible
61% – 80%	Feasible
41% – 60%	Moderately feasible
21% – 40%	Less feasible

III. RESULTS

3.1 Analysis stage

The needs analysis showed that 80% of students had difficulty understanding standing-wave concepts, mainly due to limited visualization support. Classroom management was also primarily teacher-centered, which reduced student autonomy during experiments. As a result, students continued to struggle to grasp abstract, dynamic wave concepts. These findings are consistent with earlier research indicating that traditional physics teaching often fails to promote meaningful conceptual understanding (Bao & Koenig, 2019; Deslauriers et al., 2019). Therefore, these insights provided the foundation for developing a learning approach that combines the ELC, PhET Virtual Labs, and prophetic values as an alternative framework centered on experiential learning, visual representation, and reflection.

3.2 Design stage

During the design phase, the instructional model was developed using the ELC and incorporated PhET simulations and reflective activities grounded in prophetic values. The design aimed to guide students through concrete experience, reflective observation, abstract conceptualization, and active experimentation, thereby supporting ongoing conceptual growth. This approach aligns with Kolb's experiential learning theory (Kolb, 1984) and is supported by evidence showing that interactive simulations are more effective when integrated into explicit teaching frameworks and guided activities (Banda & Nzabahimana, 2021; Hu et al., 2025).

3.3 Development stage

The development stage produced instructional tools that were subsequently evaluated through expert validation. The content and media validation results indicate that the developed tools met the criteria for feasibility, ranging from feasible to highly feasible. Content expert validation results are presented in Table 4.

Table 4. Results of content expert validation

No	Assessed aspect	Maximum score	Obtained score	Percentage (%)	Category
1	Alignment of wave material with Course Learning Outcomes (CLO)	4	4	100	Highly feasible
2	Accuracy of wave concepts and definitions	4	3	75	Feasible
3	Alignment of learning materials with the ELC syntax	4	4	100	Highly feasible
4	Depth of content and contextual examples	4	3	75	Feasible
5	Integration of learning materials with PhET simulations	4	4	100	Highly feasible
6	Clarity of conceptual understanding indicators	4	4	100	Highly feasible
	Average		3.67	87.5	Highly feasible

Table 4 presents the content expert validation results focusing on the feasibility of the instructional content and its alignment with the intended learning design for wave topics. Overall, the validation yielded a mean score of 3.67 with a feasibility percentage of 87.5%, placing the product in the Highly Feasible category. The highest ratings (100%) were achieved in the alignment of wave materials with the CLO, the alignment of materials with the ELC syntax, the integration of learning materials with PhET simulations, and the clarity of conceptual understanding indicators. These results indicate that the developed content is structurally consistent, outcome-oriented, and well supported by simulation-based activities to strengthen students' conceptual construction.

Nevertheless, two aspects received relatively lower scores (75%) and were classified as Feasible, specifically the accuracy of wave concepts and definitions and the depth of content and contextual examples. This indicates that, although the content is generally suitable for implementation, minor improvements are still necessary to enhance conceptual precision and enrich contextual examples. Such refinements are essential to ensure that learning materials promote meaningful conceptual understanding rather than just procedural completion (Kolb, 1984; Bao & Koenig, 2019). Media expert validation results are shown in Table 5.

Table 5. Results of media expert validation

No	Assessed aspect	Maximum score	Obtained score	Percentage (%)	Category
1	Alignment of PhET visual design with learning objectives	4	4	100	Highly feasible
2	Clarity of simulation usage instructions	4	3	75	Feasible
3	Interactivity and ease of navigation	4	3	75	Feasible
4	Alignment of PhET simulations with ELC stages	4	3	75	Feasible
5	Integration of media with students' reflective activities	4	3	75	Feasible
6	Media support for understanding wave concepts	4	4	100	Highly feasible
	Average		3.33	83.3	Highly feasible

Table 5 reports the media expert validation results regarding the quality and feasibility of the PhET-based media within the ELC-oriented learning design. The overall evaluation yielded a mean score of 3.33 and a feasibility percentage of 83.3%, placing it in the Highly Feasible category. Two aspects received the highest scores (100%): the alignment of PhET visual design with learning objectives and the media support for understanding wave concepts. These findings indicate that the selected simulation media are pedagogically relevant and provide strong visual support for conceptual understanding of wave phenomena.

Four aspects were rated as feasible (75%): clarity of simulation usage instructions, interactivity and ease of navigation, alignment of PhET simulations with the ELC stages, and integration of media with students' reflective activities. This pattern implies that the media are suitable for use but would benefit from stronger instructional scaffolding, particularly clearer guidance and more explicit integration of reflective tasks, so that simulation use does not remain at the level of visual exploration. This interpretation is consistent with previous studies emphasizing that interactive simulations are most effective when embedded within clear instructional structures and guided learning activities (Banda & Nzabahimana, 2021; Hu et al., 2025).

In addition, these results reinforce the role of expert validation in technology-based instructional development to ensure conceptual accuracy, media quality, and instructional design coherence prior to implementation (Plomp, 2013; Nieveen, 1999). In line with R&D principles, the convergence of feasibility ratings from content and media experts indicates that the developed classroom management guide and PhET-based learning design were suitable for classroom implementation (Branch, 2010; Molenda, 2015).

3.4 Implementation stage

The implementation stage aimed to examine the effectiveness of the developed classroom management approach in improving students' conceptual understanding of wave topics among fifth-semester Physics Education students in the 2024–2025 academic year. Effectiveness was evaluated by comparing pre-test and post-test scores, as presented in Table 6.

Table 6. Pre-test, Post-test, and N-gain scores

Test	Average score	Category
Pre-test	42.50	Low
Post-test	85.40	High
N-gain	0.5	High

Table 6 illustrates a significant enhancement in students' conceptual understanding. The average score increased from 42.50 (pre-test) to 85.40 (post-test). To evaluate the effectiveness quantitatively, N-gain analysis was conducted. The N-gain value of 0.75 is categorized as high according to Hake's criteria (Coletta & Steinert, 2020), indicating substantial learning gains following the intervention. This improvement can be analyzed in terms of the characteristics of the ELC, which endorses active engagement and progressive knowledge construction through experience, reflection, conceptualization, and experimentation. PhET virtual laboratories have likely contributed to students' ability to visualize wave phenomena that are otherwise challenging to observe directly and to enabling repeated manipulation of variables within a controlled environment, in line with previous research (Banda & Nzabahimana, 2023; Hu et al., 2025). Moreover, the incorporation of prophetic values has augmented the reflective aspect of learning by motivating students to link scientific concepts with meaning and values, thereby fostering more holistic learning experiences (Brown et al., 2023; Wulansari & Khotimah, 2019).

3.5 Evaluation stage

The evaluation stage also examined the integration of prophetic values during PhET-based practicum activities through structured observations. The results of the observations are summarized in Table 7.

Table 7. Results of the validation of prophetic values integration in PhET-based practicum

No	Prophetic value	Indicator in PhET-based practicum	Score (%)	Category
1	Scientific Honesty (Shiddiq)	Students accurately record PhET simulation observations without data manipulation	90	Very feasible
2	Responsibility (Amanah)	Students complete PhET practicum tasks according to established procedures and timelines	85	Very feasible
3	Openness & Reflection (Tabligh)	Students openly communicate simulation exploration results and reflect on wave concepts	80	Feasible
4	Scientific Accuracy (Fathanah)	Students correctly analyze relationships among wave variables using PhET simulations	88	Very feasible
5	Collaboration	Students actively collaborate in groups during PhET-based exploration and discussion	85	Very feasible
6	Spiritual Awareness	Students reflect on the orderliness of wave phenomena as part of divine creation	82	Very feasible
		Average	85	Very feasible

The observation results indicate an average percentage of 85.0%, categorized as very feasible, suggesting that prophetic values were meaningfully enacted during PhET-based practicum activities. Indicators related to honesty, responsibility, and scientific accuracy achieved high scores, consistent with the nature of simulation-based inquiry that requires independent observation, objective recording, and analytical reasoning. Collaboration and openness were also supported through group discussions and presentations of simulation exploration outcomes.

Nevertheless, these results should be interpreted cautiously because the study involved only 14 participants, which limits generalizability. Accordingly, the findings are best positioned as preliminary evidence. In comparison, the conceptual learning gains remain consistent with literature reporting that experiential learning and interactive simulations can enhance conceptual understanding in physics (Banda & Nzabahimana, 2021; Deslauriers et al., 2019). The primary contribution of this study is the integration of prophetic values within the ELC–PhET framework, which enriches the reflective dimension of learning and remains relatively underexplored in comparable empirical research.

IV. DISCUSSION

Based on the findings of this study, the development of a classroom management guide grounded in the ELC and integrated with prophetic values within PhET Virtual Labs contributed to a meaningful improvement in students' conceptual understanding of wave phenomena. This finding is consistent with Theasy et al (2021), who reported that PhET simulations provide strong visual representations that can help reduce misconceptions in abstract physics topics. However, this study extends prior work by employing PhET as an instructional medium and embedding it within a systematic ELC framework that structures students' learning trajectories from exploration to conceptual consolidation.

The role of the ELC was particularly evident in the Reflective Observation phase, where students were not limited to manipulating simulation parameters but were guided to interpret patterns, compare outcomes with expectations, and articulate conceptual relationships derived from observed phenomena. As argued by Abdulwahed and Nagy (2013), Kolb's learning cycle enables practical experiences to be transformed into deeper knowledge restructuring, thereby supporting more durable conceptual understanding. In this context, the ELC served as a pedagogical scaffold, ensuring that simulation activities functioned as concept-building experiences rather than isolated demonstrations.

In addition, the effectiveness of the intervention can be understood through the lens of classroom management. Effective classroom management is widely recognized as a fundamental condition for instructional success because it supports students' engagement, task focus, and orderly learning processes (Emmer & Sabornie, 2015). In this study, the classroom management guide provided explicit guidance on how students transitioned between ELC stages in the PhET environment, strengthening the coherence between learning activities and targeted conceptual outcomes. This coherence is important because interactive tools alone do not automatically produce conceptual change unless students are guided through structured inquiry and reflection.

Beyond cognitive outcomes, the integration of prophetic values added an additional dimension to the learning process. Aulia et al (2022) emphasize that integrating prophetic values into science education can help develop learners with strong moral integrity. In the present study, prophetic values were positioned as operational learning norms within simulation-based activities, supporting students' responsibility and honesty during learning and data-reporting practices. The emergence of *Fathanah* (intellectual acumen) was also evident when students solved complex problems related to wave interference phenomena, suggesting that intellectual development and value-oriented reflection can be fostered concurrently within a well-managed learning environment.

V. CONCLUSION AND SUGGESTION

Based on the research and development of a prophetic-integrated classroom management guide grounded in the ELC within PhET Virtual Labs, three main conclusions can be drawn. First, the developed product demonstrated strong validity, as expert evaluation categorized it as highly feasible, with a material validation mean score of 3.67 and a media/instructional design validation mean score of 3.33. Second, the implementation of the guide was cognitively effective in improving students' conceptual understanding of wave phenomena, as reflected by the increase in mean scores from 42.50 (pre-test) to 85.40 (post-test) and an N-gain of 0.75 (high category). Third, the integration of prophetic values was meaningfully enacted during virtual practicum activities, particularly in *Shiddiq* (90%) and *Amanah* (85%), which were reflected in students' honest data reporting and responsible task completion in accordance with the ELC learning cycle.

Despite these findings, this study has limitations that should be considered when interpreting its results. The trial involved only 14 students in a single class, which restricts the generalizability and strength of the effectiveness claims. Future research is therefore recommended to conduct broader field trials with larger, more diverse participant groups to assess the model's stability across learner characteristics and instructional contexts. In addition, subsequent studies are encouraged to examine the impact of this classroom management model on other learning outcomes, such as students' critical thinking skills and digital literacy. Despite its limitations, this study advances physics education by presenting an integrated teaching framework that methodically combines ELC-based classroom management, PhET virtual laboratories, and the internalization of prophetic values. This approach supports conceptual understanding while also promoting value-driven reflection and integrity in simulation-based physics instruction.

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