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Preliminary Study on A Guided Inquiry-Virtual Lab Worksheet for Developing Science Process Skills

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Abstract

The transition to distance learning has emphasized the importance of accessible and pedagogically sound science instruction, particularly in courses requiring experimental engagement. Virtual laboratories combined with guided inquiry models have emerged as effective alternatives to support conceptual understanding and scientific reasoning. This study examines students' perceptions of worksheets developed based on virtual laboratories and guided inquiry to support science process skills in basic physics courses. Data were collected from 25 students using a structured questionnaire comprising 10 items, which covered five domains: distance learning, science process skills, guided inquiry, virtual laboratory use, and worksheet development. Descriptive quantitative analysis showed that distance learning received the highest mean score (M = 3.60), with no negative responses reported. Positive perceptions were also observed for virtual laboratory use (64% strongly agree) and worksheet development (60%). The guided inquiry domain showed a moderate mean score (M = 3.02), with female students demonstrating higher agreement (48%) than male students (16%). In the science process skills domain, the mean score reached 3.48, and 64% of students strongly agreed that virtual experiments improved their ability to interpret scientific data. These findings indicate strong student acceptance of technology-enhanced learning and highlight the pedagogical relevance of virtual-laboratory-based worksheets in distance learning environments.

Keywords: *Guided inquiry, physics, science process skills, virtual laboratory, worksheet.*

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1. INTRODUCTION

The advancement of digital technology has transformed various aspects of life, including higher education. One of its most significant impacts is the shift in learning approaches, which are no longer entirely dependent on physical interaction between lecturers and students (Saykılı, 2019). In the university context, particularly in science education, this phenomenon presents both challenges and opportunities. Experiment-based courses such as basic physics, which traditionally require direct presence in the laboratory, must now adapt to flexible learning approaches without compromising the conceptual dimensions and scientific skills that constitute the core of science education (Kácovský, 2023).

To address these challenges, the virtual laboratory has emerged as one of the alternatives (McCusker et al., 2018). This technology enables students to conduct experimental simulations digitally, with interactive features and dynamic visualization of phenomena, thereby providing a learning experience that closely resembles real experiments. Virtual laboratories can also be accessed without time and location constraints, allowing students to repeat experiments until they achieve a comprehensive understanding (Alnagrat et al., 2023; Nadiyyah et al., 2025). Several studies have shown that the use of virtual laboratories can enhance students' cognitive (Sapriati et al., 2023) and affective engagement (Husnaini & Chen, 2019; Wu et al., 2025).

Nevertheless, the effectiveness of virtual laboratories is strongly influenced by the pedagogical approaches that accompany them. One such approach proven to support the development of scientific thinking skills is guided inquiry (Maknun, 2020; Suardana et al., 2019). This approach emphasizes active student engagement in a structured scientific exploration process through inquiry stages such as formulating questions, designing experiments, analyzing data, and drawing conclusions. The role of the lecturer as a facilitator is also crucial in providing gradual guidance according to students' level of readiness (Cahaya et al., 2020). Several studies indicate that guided inquiry can improve conceptual understanding and critical thinking skills (Maknun, 2020), as well as students' science process skills in learning (Arantika et al., 2019).

The integration of virtual laboratories and guided inquiry approaches in the form of worksheets represents a potential innovation to support active and meaningful learning in the digital era (Husnaini & Chen, 2019). Such worksheets serve as structural tools that not only guide experimental procedures but also design reflective and analytical activities that foster students' cognitive engagement (Mutlu, 2020). In other words, worksheets based on virtual laboratories and guided inquiry can function as media that stimulate students to connect theory with practice and develop science process skills (Jannah et al., 2025).

Beyond serving as instruments for conducting experiments, pedagogically designed worksheets also act as a medium for the deeper internalization of scientific skills. In the context of science education, science process skills encompass both basic skills such as observation, measurement, classification, and communication, as well as integrated skills such as formulating hypotheses, designing experiments, and interpreting data (Gizaw & Sota, 2023). These skills are not only essential for academic success but also form the foundation of scientific reasoning (Hacıeminoğlu et al., 2022). Therefore, worksheet development should not merely be procedural but must also be exploratory and reflective (Husnaini & Chen, 2019).

Previous studies have demonstrated the effectiveness of virtual laboratories and guided inquiry when applied separately. However, there remains a limited number of studies integrating the two into a single learning tool. Thus, this research seeks to fill that gap through a preliminary study that explores students' perceptions of the development of worksheets based on guided inquiry and virtual laboratories. Student perceptions as end users provide important insights into the development process, as they can reflect their level of readiness, needs, and expectations toward the learning tools to be implemented.

2. METHODS

This research serves as the initial phase of a development study that adheres to the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). This article specifically focuses on the first phase, namely needs analysis, which aims to explore students' perceptions of the planned development of experiment worksheets based on virtual laboratories with a guided inquiry approach in basic physics learning. A descriptive quantitative research design was employed, with data collected through online questionnaires and interviews involving 25 active students of Universitas Terbuka who had previously taken the basic physics course in the distance learning system. Data collection was conducted using a non-probabilistic approach through two distinct sampling techniques: first, incidental sampling was applied in the quantitative data collection by engaging students who voluntarily completed the questionnaire during the data collection period; and second, purposive sampling was employed for qualitative data collection through interviews, in which five students were deliberately selected to represent the diversity of responses in the questionnaire and to possess specific characteristics (Asrulla et al., 2023). This selection was intended to obtain deeper insights and enhance the interpretation of the quantitative findings.

The research instrument used was a Likert-scale questionnaire with four response options. The questionnaire was developed based on five key aspects considered relevant to the focus of development, namely: (1) distance learning, (2) science process skills, (3) guided inquiry model, (4) use of virtual laboratories, and (5) worksheet development. Each aspect consisted of two statements designed to specifically measure students' perceptions of the respective aspect. Data collection was conducted via the Google Form platform. Subsequently, the collected data were meticulously compiled and analyzed employing descriptive statistics. The primary objective was to calculate the mean score for each aspect, utilizing Equation 1. These mean scores were subsequently categorized based on the scale range specified in Equation 2.

$$\bar{x} = \frac{\sum x}{n} \qquad (1)$$

$$Rs = \frac{M-m}{b} \quad (2)$$

Where $\overline{\boldsymbol{x}}$ represents the mean score, $\sum \boldsymbol{x}$ denotes the total score, $\boldsymbol{n}$ represents the number of respondents, $\boldsymbol{Rs}$ denotes the score range, $\boldsymbol{M}$ and $\boldsymbol{m}$ represent the highest and lowest scores, and $\boldsymbol{b}$ denotes the rating scale from which the categories in Table 1 were derived (D. S. Putri & Santoso, 2020).

Table 1. Categories of mean scores

Score	Category
$3.26 \leq x \leq 4.00$	High
$2.51 \leq x \leq 3.25$	Moderate
$1.76 \leq x \leq 2.50$	Low
$1.00 \leq x \leq 1.75$	Very Low

(D. S. Putri & Santoso, 2020)

In addition to mean analysis, frequency distributions of student responses were examined to provide a more comprehensive overview. Furthermore, gender-based comparisons between male and female respondents were analyzed across each perceptual aspect. These findings serve as the foundation for assessing students' readiness and requirements for the product's development in the subsequent design phase.

3. RESULT AND DISCUSSION

This research seeks to provide an initial assessment of students' perceptions regarding the development of worksheets based on guided inquiry and virtual laboratories designed to enhance science process skills. The analysis was conducted utilizing three primary data sets: the distribution of student responses, the average score for each aspect, and gender-based comparisons of perceptions.

3.1 Student Response Distribution

Based on the analysis presented in Figure 1, most respondents demonstrated positive perceptions toward the planned development of the worksheet. The distribution of responses across the five aspects measured by the research instrument revealed a dominance of the strongly agree category, indicating students' level of acceptance and readiness to utilize technology as a learning medium in basic physics. The highest percentage of support was observed in items related to the effectiveness of distance learning (66%) and the ease of understanding material through virtual laboratory experiments (64%). This finding aligns with Sholikah (2021), who emphasized that the success of distance learning strongly depends on interactive media that foster active student engagement (Sholikah & Harsono, 2021).

Items related to science process skills and conceptual reinforcement through the virtual lab also received high responses. Students stated that virtual experiment simulations facilitated their observation and data analysis. This perspective aligns with Alnagrat (2022), who found that virtual laboratories can enhance science process skills by providing clear visual representations and repeated exploration opportunities, without the physical limitations of traditional laboratories (Alnagrat et al., 2023). In contrast, responses to items in the guided inquiry approach demonstrated greater diversity, with 16% of students expressing reservations or disagreement. Interview results (Table 3) revealed that students attributed their limited experience with inquiry-based learning to the perceived rigidity of the model when applied exclusively in online learning. Weerasinghe (2012) underscored the importance of active engagement and structured guidance in inquiry models, yet emphasized that inquiry can still be successful without a facilitator when the learning environment facilitates student interaction (Weerasinghe, T. A. et al., 2012). Consequently, facilitation strategies in virtual laboratories should be designed to be flexible, providing direction while allowing students to manage their investigations and collaborate independently.

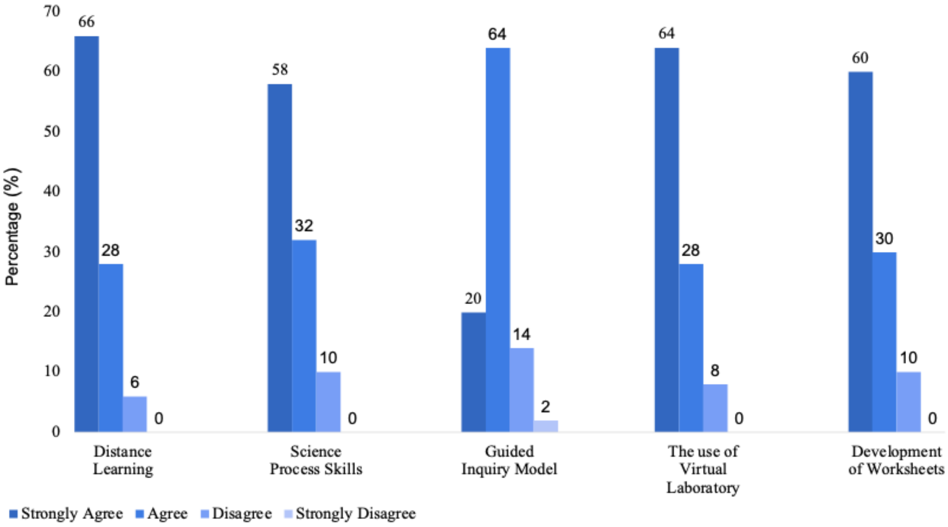

Figure 1. Distribution of student responses by aspects

The instrument results indicate that students possess a high level of readiness and exhibit positive preferences for learning innovations that incorporate virtual laboratories with guided inquiry-based worksheets. This tendency provides a strong foundation for subsequent development stages, aligning with Panjaitan's (2020) findings, which demonstrated that guided inquiry-based learning effectively enhances science process skills by presenting problems and providing systematic guidance while simultaneously enabling students to independently explore and discover concepts (Panjaitan & Siagian, 2020).

3.2 Categories of Student Perceptions

Quantitative analysis of the five primary aspects corroborated the findings derived from the response distribution. The results indicate that, in general, students demonstrated a positive attitude toward the development of technology-based learning and the guided inquiry approach.

The preliminary analysis showed that students were well-prepared to adopt technology-based learning, particularly in distance learning and the use of virtual laboratories. These two aspects ranked yielded the highest mean scores (M = 3.60 for distance learning and M = 3.56 for virtual laboratory), reflecting students' comfort and adaptability in digital learning environments. This finding aligns with Guo (2023), who emphasized that the success of online learning is strongly influenced by interactive media that sustain students' cognitive engagement (Guo et al., 2023).

Table 2. Mean scores and categories for the analyzed aspects

No.	Aspects	Mean	Category
1	Distance Learning	3.60	High
2	Science Process Skills	3.48	High
3	Guided Inquiry Model	3.02	Moderate
4	The use of Virtual Laboratory	3.56	High
5	Development of Worksheets	3.50	High

In addition, the aspect of worksheet development also received positive responses (M = 3.50), suggesting that students perceived worksheets not merely as administrative tools but as instructional scaffolds that support systematic thinking and experimentation. This aligns with findings showing that worksheet designs aligned with inquiry stages can support the strengthening of science process skills (Tiaradipa et al., 2020). Meanwhile, science process skills obtained a slightly lower score (M = 3.48), indicating the need for reinforcement through explicit guidance and structured activities. Suryanti (2020) also confirmed that science process skills develop more optimally when students are provided with adequate scaffolding in inquiry-based learning (Suryanti et al., 2020).

Interestingly, the guided inquiry model was the only aspect categorized as moderate (M = 3.02). This result indicates that students need a more comprehensive introduction and practice with inquiry stages, including formulating questions, designing experiments, and drawing conclusions. The relatively lower perception of this aspect provides important insights for researchers to design worksheets with step-by-step guidance, helping students adapt to the process of independent yet structured scientific investigation.

This moderate perception of the guided inquiry model suggests that students are not yet fully acquainted with inquiry-based learning, particularly in online settings. Transitioning from a teacher-centered approach to guided inquiry can be challenging, necessitating both cognitive readiness and a period of adaptation. Based on the interview findings, some students perceived guided inquiry as overly rigid, particularly when all steps were predetermined. This indicates that in virtual learning environments, guided inquiry should be implemented more flexibly, considering students' prior learning experiences and providing adaptive levels of guidance (Maknun, 2020).

3.3 Comparison of Perceptions by Gender

Across the five aspects examined in this research, gender-based differences were observed. The data presented in two vertical charts showed that female students generally reported a higher level of acceptance of technology use and the guided inquiry-based learning approach compared to their male counterparts.

Figure 2 shows clear gender-based differences in perceptions of worksheet development and the use of virtual laboratories. Female students consistently reported more positive responses, particularly in guided inquiry, technology use, and instructional support. For instance, 48% of female students strongly agreed with the guided inquiry model, compared to only 4% of male students. This indicates that female students place greater emphasis on structure and guidance in scientific exploration, reinforcing previous evidence that scaffolding in inquiry-based learning effectively enhances science process skills (Tiaradipa et al., 2020).

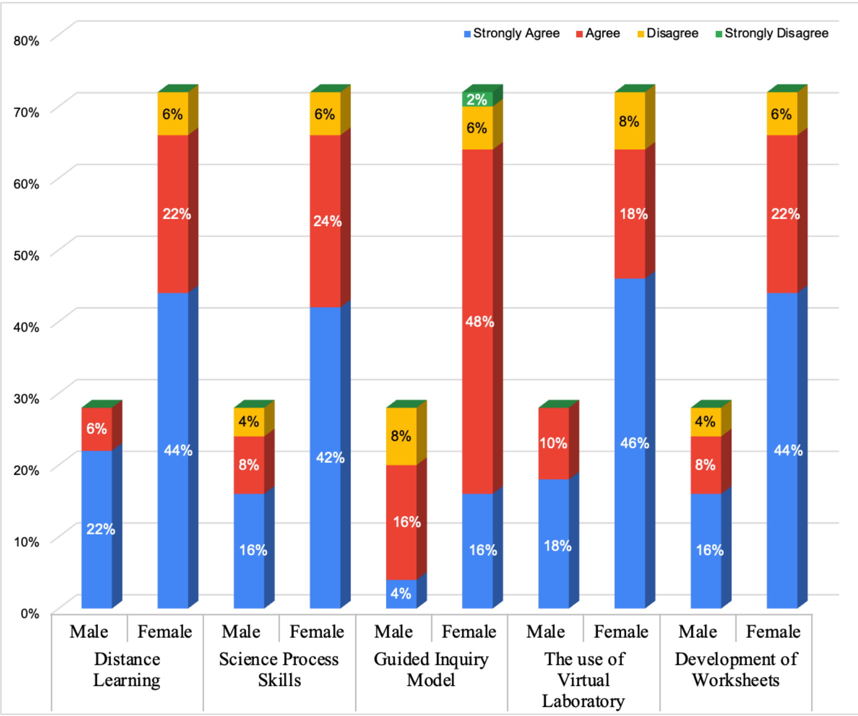

Figure 2. Comparison of students' perceptions by gender

A similar tendency appeared in the virtual laboratory aspect, where 46% of female students strongly agreed. This finding aligns with Vergara (2023), who reported that simulation-based learning experiences can increase motivation while reducing gender gaps in STEM (Vergara, 2023). Putri (2021) further demonstrated that integrating virtual laboratories with inquiry-based learning can improve students' scientific literacy (N-Gain = 0.441) (Putri et al., 2021). Likewise, Abdelmoneim (2022) highlighted the effectiveness of virtual laboratories in fostering expert thinking skills and decision-making (Abdelmoneim et al., 2022). Within this study, inquiry-based worksheets played a crucial role in guiding the use of virtual laboratories, enabling students not only to conduct experiments but also to systematically develop science process skills. Regarding science process skills, 42% of female students strongly agreed compared to only 16% of male students, indicating that female students were more confident in structured learning approaches such as observation, data interpretation, and concluding.

The findings indicate that female students showed greater readiness toward guided inquiry, virtual laboratories, and worksheets compared to male students. Female students appeared to value instructional structure and scaffolding more, while male students showed more varied responses, with some favoring flexible and practice-oriented learning models. These findings are consistent with recent cognitive studies that highlight visuospatial advantages in males (Barel & Tzischinsky, 2018; Lager et al., 2024) and verbal as well as self-regulation advantages in females (Barel & Tzischinsky, 2018; Hirnstein et al., 2023). Furthermore, Liu (2022) confirmed that inquiry embedded in virtual laboratories has long-term effects on scientific literacy (Liu et al., 2022). Thus, these results extend the evidence that the success of technology-based science learning is determined not only by instructional design but also by cognitive tendencies and gender-specific learning styles regarding scaffolding and digital interactivity. These findings were also reinforced by student interview results (**Table 3**).

Table 3. Student interview results

Code	Gender	Statements	Aspect
R1	Female	"i found it easier to understand the course using the virtual lab worksheet because the steps were clear and made me think logically when analyzing data."	worksheet, science process skills
R2	Male	"i think guided inquiry is too rigid if all the steps are predetermined. i prefer experiments where i can try my own way."	guided inquiry
R3	Female	"virtual labs really help because i can repeat the experiments anytime. i feel more confident to try without fear of making mistakes."	virtual lab
R4	Male	"i like distance learning because i can study independently, but i still need some guidance during experiments, so i don't get lost."	distance learning, worksheet
R5	Female	"guided inquiry works well for me - it gives a thinking structure but still challenges me to draw conclusions on my own."	guided inquiry, science process skills

The interview results revealed that students generally perceived the worksheet, virtual laboratory, and guided inquiry as complementary components in the learning process. Female respondents (R1, R3, R5) emphasized the role of worksheets and guided inquiry as scaffolding tools that supported logical reasoning, data analysis, and independent conclusion drawing, while repeated practice in the virtual laboratory enhanced their confidence in experimentation. These insights are consistent with the quantitative data, which showed positive responses toward worksheets (M = 3.50) and guided inquiry (48% of female students strongly agreed). Well-designed worksheets were thus viewed as effective in linking inquiry stages with science process skills and in preparing students to engage with simulation technology.

Male respondents (R2, R4), in contrast, emphasized the need for flexibility and a balance between autonomy and guidance. R2 perceived overly rigid guided inquiry as limiting exploration, while R4 appreciated the autonomy offered by distance learning but still required direction to stay on track. These insights suggest that worksheet development should integrate two essential elements: clear instructional structure to foster science process skills and flexibility to accommodate diverse learning preferences. Thus, the interview data complement the quantitative findings and underscore the importance of designing guided inquiry worksheets that are interactive, adaptive, and responsive to students' needs.

These gender-based differences point to the need for a more adaptive approach in designing guided inquiry-based virtual learning. The findings show that female students tend to respond better to structured scaffolding, while male students often prefer more flexibility and opportunities to explore. This means that worksheet design should not rely on a one-size-fits-all approach, but rather offer varying levels of guidance to support different learning preferences better (Barel & Tzischinsky, 2018; Hirnstein et al., 2023).

Based on the findings of this preliminary study, several practical recommendations can be considered for the worksheet development phase. First, flexible scaffolding should be incorporated by providing clear guidance at the beginning, such as step-by-step procedures and guiding questions, and then gradually reducing the level of support to encourage more independent inquiry. Second, the worksheet can be designed to allow some flexibility in the inquiry process, so students have opportunities to explore different approaches while still working toward the intended science process skills. Third, the design should also take into account gender-related learning preferences by balancing structured guidance with opportunities for exploration. Therefore, these approaches are expected to improve the effectiveness of guided inquiry-based virtual laboratory worksheets in supporting a wider range of learners.

4. CONCLUSION

The preliminary study indicates that students hold positive perceptions of the worksheet development. The highest perceptions were observed in distance learning, the use of virtual laboratories, science process skills, and worksheet development, which were generally categorized as high. Although the mean score for the guided inquiry aspect was at a moderate level, the response distribution showed a strong positive tendency, particularly among female students. This finding aligns with the interview results, which emphasize the importance of balancing instructional structure and flexibility in practice. These results suggest that students are prepared to engage in technology-based and guided inquiry learning, providing a solid foundation for proceeding to the design and development phase of the worksheet. Accordingly, this study makes an initial contribution to the design of virtual laboratory-based learning strategies that are adaptive to remote learning contexts, while also promoting the development of science process skills and serving as a basis for the subsequent design and development stages within the ADDIE model, particularly in integrating flexible scaffolding strategies to accommodate diverse student characteristics.

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