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Implementing Inquiry-Based Learning With a Sound Meter Application to Improve Understanding of Sound Waves

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ABSTRACT

This study examined the implementation of inquiry-based learning supported by an Android Sound Meter application to strengthen students' understanding of sound-wave concepts, particularly sound intensity level. The intervention addressed limited laboratory equipment and connected physics concepts with everyday noise measurements. A one-group pretest-posttest quasi-experimental design was implemented with 33 students in Grade XI MIPA 4 at SMAN 1 Giri Banyuwangi. Students followed an application-assisted inquiry sequence involving problem orientation, application integration, hypothesis development, measurement and data collection, explanation, generalization, and reflection. The mean score increased from 61.33 (SD = 13.587) on the pretest to 80.091 (SD = 13.947) on the posttest, while the reported mastery proportion increased from 33.28% to 80.09%. The source manuscript also reports t = -0.562; because no degrees of freedom, p value, confidence interval, or test specification is provided, this statistic is not interpreted as evidence of statistical significance. The findings therefore support a descriptive improvement in conceptual performance and illustrate how smartphone sensing can facilitate contextual inquiry when conventional apparatus is limited.

Keywords: Android application; inquiry-based learning; physics education; sound intensity; sound meter

INTRODUCTION

Physics learning is most productive when students connect formal representations with observable phenomena and use evidence to refine explanations. Inquiry-oriented science instruction can support conceptual understanding, scientific reasoning, and active participation when learners formulate questions, gather evidence, analyze observations, and communicate explanations (National Research Council, 2000; Minner et al., 2010; Furtak et al., 2012; Pedaste et al., 2015; Lazonder & Harmsen, 2016). These principles are especially relevant for acoustics, where abstract quantities such as intensity, intensity level, frequency, and distance from a source can be linked directly to measurable events in students' daily environments.

Mobile technologies create additional opportunities for such contextual investigation. Smartphones combine portability, computation, visualization, microphones, and sensors, allowing students to collect data outside a conventional laboratory and to revisit measurements during discussion (Sung et al., 2016; Crompton & Burke, 2018; Crompton et al., 2017; Zacharia et al., 2015; de Jong et al., 2013). Research on smartphone sound-level applications shows that their accuracy varies across devices and applications, but

calibrated or carefully selected tools can provide useful measurements for educational and screening contexts (Kardous & Shaw, 2014; Murphy & King, 2016; McLennon et al., 2019; Nast et al., 2014; Celestina et al., 2018). Accordingly, smartphone measurements should be treated as instructional evidence rather than as substitutes for certified sound-level meters in regulatory or occupational decisions.

The source study was motivated by limited sound-wave apparatus at SMAN 1 Giri Banyuwangi and by students' interest in Android-supported learning. It therefore integrated a Sound Meter application into an inquiry sequence to help students investigate everyday noise and understand sound intensity level. The study asked whether students' understanding of sound-wave material improved after this application-assisted inquiry experience.

LITERATURE REVIEW

Inquiry-Based Physics Learning

Inquiry learning positions students as active constructors of explanations while the teacher structures productive questioning, evidence collection, and reflection. Meta-analytic and review evidence indicates that inquiry is most effective when appropriate guidance is provided rather than when learners are left to discover complex ideas without support (Alfieri et al., 2011; Kirschner et al., 2006; Hmelo-Silver et al., 2007; Bell et al., 2010; Maaß & Artigue, 2013; Prince & Felder, 2006). In physics education, active and inquiry-oriented approaches are also associated with stronger conceptual learning than transmission-only instruction (Hake, 1998; Freeman et al., 2014; Meltzer & Thornton, 2012; Wieman, 2014). Practical investigation can further develop process skills and scientific attitudes when experiments are explicitly connected to conceptual reasoning (Abrahams & Millar, 2008; Hofstein & Lunetta, 2004; Etkina et al., 2010).

Mobile Sensing and Digital Learning

Mobile learning can extend experimentation beyond fixed laboratory spaces and provide immediate representations of phenomena. Reviews emphasize that learning gains depend less on the novelty of the device than on alignment among pedagogy, task design, feedback, and learner activity (Wu et al., 2012; Schmid et al., 2014; Tamim et al., 2011; Hillmayr et al., 2020; Sailer & Homner, 2020). Smartphone sensors have been used in physics and science education to support authentic measurement, visualization, and student-generated data (Kuhn & Vogt, 2013; Vieyra et al., 2015; Monteiro et al., 2016; Klein et al., 2014). Multimedia principles further suggest that digital representations are most useful when they direct attention to relevant relationships rather than add extraneous information (Mayer, 2021; Ainsworth, 2006).

Sound Intensity, Noise, and Measurement

Sound intensity level is conventionally expressed on a logarithmic decibel scale. Because exposure risk depends on both sound level and duration, noise education should distinguish classroom exploration from occupational-health decisions. International guidance identifies prolonged high-level noise as a hearing-health risk and recommends evidence-based exposure management (World Health Organization, 2018; World Health Organization, 2021; NIOSH, 1998; Basner et al., 2014; Stansfeld & Matheson, 2003). The original study used an approximate 85 dB reference point to contextualize safe listening and asked students to relate measurements to everyday sound sources. This contextualization can make logarithmic intensity concepts more meaningful while also promoting responsible interpretation of measurement uncertainty (Serway & Jewett, 2018; Halliday et al., 2014; Young & Freedman, 2020).

METHODS

Design and Participants

The study used a one-group pretest-posttest quasi-experimental design. Participants were 33 students in Grade XI MIPA 4 at SMAN 1 Giri Banyuwangi. The original manuscript reports that the study was conducted in May. Students completed a pretest, participated in inquiry learning supported by a Sound Meter application, and then completed a posttest. This design can document within-group change but cannot isolate the intervention from maturation, testing, history, or other threats to internal validity because it does not include a comparison group (Shadish et al., 2002; Creswell & Creswell, 2018; Campbell & Stanley, 1963).

Table 1. One-group pretest-posttest design

Group	Pretest	Treatment	Posttest
Experimental group	T1	X: inquiry learning supported by Sound Meter	T2

Application-Assisted Inquiry Procedure

The intervention retained the source manuscript's inquiry logic and incorporated the smartphone application as a measurement tool. The instructional sequence consisted of: (1) problem orientation using everyday sound-intensity situations; (2) integration and installation of the Sound Meter application; (3) hypothesis formulation supported by a worksheet; (4) experimentation and data collection; (5) analysis of measurement data; (6) explanation through presentation of findings; (7) generalization through a shared conclusion; and (8) reflection. This sequence is consistent with guided inquiry frameworks in which teacher scaffolding supports evidence-based reasoning (Pedaste et al., 2015; Lazonder & Harmsen, 2016; Hmelo-Silver et al., 2007).



Figure 1. Application-assisted inquiry sequence in the source manuscript.



Figure 2. Sound Meter application used as a smartphone-based measurement tool.

Data Analysis

The source manuscript summarizes pretest and posttest score distributions using frequencies, relative frequencies, means, standard deviations, and mastery percentages. It also reports a t statistic of -0.562 but does not specify the exact test, degrees of freedom, p value, or confidence interval. Consequently, the present templated version preserves the reported statistic but does not infer statistical significance from it. This reporting choice follows recommendations to interpret effect evidence with transparent statistical information rather than relying on an isolated test statistic (Wasserstein & Lazar, 2016; Lakens, 2013; Cumming, 2014).

RESULTS AND DISCUSSION

Pretest and Posttest Performance

The score distribution shifted toward higher intervals after the intervention. On the pretest, the largest frequency occurred in the 53-63 interval (12 students; 36.4%), whereas on the posttest the largest frequencies occurred in the 75-85 interval (15 students; 45.4%) and the 86-100 interval (12 students; 36.37%).

Table 2. Pretest score distribution (N = 33)

Score interval	Frequency	Relative frequency
42-52	10	30.3%
53-63	12	36.4%
64-74	5	15.1%
75-85	4	12.12%
86-100	2	6.06%

Table 3. Posttest score distribution (N = 33)

Score interval	Frequency	Relative frequency
42-52	3	9.1%
53-63	2	6.1%
64-74	1	3.0%
75-85	15	45.4%
86-100	12	36.37%

Table 4. Summary of reported learning outcomes

Measure	Pretest	Posttest	Change
Mean	61.33	80.091	+18.761
Standard deviation	13.587	13.947	+0.360
Reported mastery	33.28%	80.09%	+46.81 percentage points

The mean increased by 18.761 points, and the reported mastery percentage increased by 46.81 percentage points. These descriptive changes are educationally notable and are consistent with research showing that guided inquiry, active learning, and technology-supported experimentation can strengthen conceptual engagement when learners manipulate evidence and discuss explanations (Furtak et al., 2012; Freeman et al., 2014; Hillmayr et al., 2020). Nevertheless, the one-group design does not establish that the intervention alone caused the change. The reported t = -0.562 is also insufficient, by itself, to support the source manuscript's claim of a statistically significant effect because essential inferential details are absent.

Learning Through Contextual Sound Measurement

The instructional value of the Sound Meter application lies in making an otherwise abstract decibel quantity immediately observable. Students measured sound in several everyday settings and used the resulting values as evidence during inquiry. This type of situated measurement can support conceptual bridging between equations, graphical displays, and lived experience (Ainsworth, 2006; Mayer, 2021; Kuhn & Vogt, 2013). At the same time, smartphone microphones differ in hardware, automatic gain control, calibration, and frequency response; therefore, comparisons should emphasize patterns and conceptual reasoning unless devices are calibrated against a reference instrument (Kardous & Shaw, 2014; Murphy & King, 2016; McLennon et al., 2019).

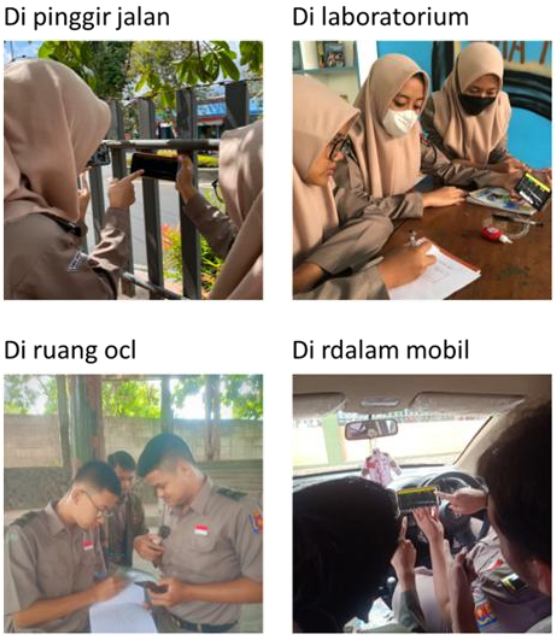


Figure 3. Student sound-measurement activities in different contexts, as documented in the source manuscript.

Instructional Implications

For physics teachers working with limited laboratory apparatus, smartphone sensing can serve as a low-cost complement to formal equipment. The strongest instructional use is not merely reading a decibel value, but requiring students to predict, measure, compare, explain discrepancies, and reflect on uncertainty. Such tasks align with evidence-centered inquiry and can promote critical reasoning, collaboration, and scientific practices (National Research Council, 2012; Osborne, 2014; Duschl & Bybee, 2014). Teachers should also explicitly discuss hearing-health guidance and the limitations of phone-based measurements so that students do not treat an educational app as a certified safety instrument.

LIMITATIONS

Four limitations constrain interpretation. First, the study used a single class and no comparison group. Second, the manuscript does not report instrument reliability, item-level validity evidence, or an effect size. Third, the reported t statistic (-0.562) lacks degrees of freedom, p value, confidence interval, and test specification. Fourth, the source manuscript contains a small internal discrepancy in the initial mastery percentage: the results section reports 33.28%, whereas the conclusion reports 32.58%. This version uses 33.28% in the results table because it is the value reported alongside the pretest statistics, while preserving the discrepancy here for transparency.

CONCLUSION AND RECOMMENDATIONS

Application-assisted inquiry provided a practical framework for connecting sound-wave concepts with measurements from students' everyday environments. For the 33 participating students, the mean score increased from 61.33 to 80.091 and the reported mastery level increased from 33.28% to 80.09%. These results support a descriptive improvement following the intervention, but causal and statistical-significance claims require a stronger design and complete inferential reporting. Future studies should include a comparison group, calibrated measurement procedures, validated conceptual instruments, effect sizes with confidence intervals, and explicit reporting of the inferential test. The approach can also be extended to other physics topics where reliable smartphone sensors can support guided investigation.

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