# Comparative Effectiveness of Digital and Conventional Oscilloscopes in Resonance Tube Practicum

**Desi Susanti[1,2*], Yudhiakto Pramudya[1], & Ishafit[1]**
[1]Physics Education Department, Universitas Ahmad Dahlan, Indonesia
[2]SMAN 1 Sendawar, Indonesia
*Corresponding Author: desi.susantiaisha@gmail.com

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***Abstract -*** *This study investigates the comparative effectiveness of digital and conventional oscilloscopes in physics learning, focusing on the resonance tube practicum as a medium for understanding acoustic wave phenomena. Digital tools such as the Soundcard Oscilloscope have been proposed as innovative and low-cost alternatives to conventional laboratory equipment, addressing resource limitations in many schools. A quantitative quasi-experimental nonequivalent control group design was employed involving two classes of eleventh-grade students. Learning outcomes were measured using validated pre-test and post-test instruments. Data were analyzed through descriptive statistics, Wilcoxon Signed Rank tests for within-group changes, and Mann–Whitney U tests for between-group comparisons due to non-normal data distribution. The experimental group demonstrated significant improvement in learning outcomes (p = 0.003), confirming the effectiveness of the digital tool, while the control group did not (p = 0.094). Although the Mann–Whitney test indicated no significant difference between groups (p = 0.873), N-Gain analysis revealed a notable contrast: a low gain (0.095) in the experimental group versus a decrease (–0.262) in the control group. This research offers novelty by directly comparing digital and conventional oscilloscopes in resonance tube experiments, highlighting the gap between statistical significance and pedagogical effectiveness. The findings demonstrate that the Soundcard Oscilloscope serves as a viable, low-cost alternative that yields greater learning gains than its conventional counterpart. These results underscore the potential of integrating affordable digital laboratory tools with active learning strategies to enhance conceptual understanding, particularly in resource-constrained educational contexts.*

***Keywords***: *Soundcard Oscilloscope; Conventional Oscilloscope; Learning Outcomes; Nonparametric Analysis; Resonance Tube Practicum*

## INTRODUCTION

Physics is the foundation of all sciences that studies the behavior and structure of matter (Giancoli, 1998). As an experimental science, as asserted by Young and Freedman (2002), physics requires the verification of theories through experiments to develop universally applicable principles. In line with this view, Supardi and Kartono (2017) emphasize that physics adopts the scientific method. Therefore, effective physics learning demands active student involvement in the process of problem-solving and experiment design (Erlinda, 2016). Practicum-based learning has numerous benefits, including deepening students' conceptual understanding and strengthening scientific skills (Bretz et al., 2013; Supasorn, 2012; Fadly et al., 2017).

However, the availability of equipment often becomes a significant obstacle. Initial observations at SMA Negeri 1 Sendawar showed that only one conventional oscilloscope was available. This issue is widespread in West Kutai Regency, where the majority of high schools possess fewer than three units or none at all. Oscilloscopes are crucial for visualizing waveforms and measuring key parameters in sound wave material (Dasatrio, 2013; Telaumbanua, 2022). Due to the high cost and limited quantity of this essential instrument, the resonance tube topic is often taught theoretically (Amalissholeh et al., 2023; Angraeni, 2017), hindering students from gaining deep understanding through direct experience.

In response to this obstacle, technological advancements have led to various digital alternatives (Ambusaidi et al., 2018; Lawrence et al., 2023). One promising option is the Soundcard Oscilloscope, developed by Zeitnitz (2008), which transforms personal computers into functional oscilloscopes (Subarna, 2016). Previous studies have explored its technical reliability in the Doppler Effect (Ristanto & Santoso, 2016) and alternating current (Hasanah et al., 2017). A prior study by Susanti and Ishafit (2025) specifically found that using the Soundcard Oscilloscope in a closed resonance tubes practicum led to a significant improvement in learning outcomes compared to a conventional oscilloscope.

Other digital applications, such as Audacity, Tone Generator, Spectroid, and Phyphox, also show potential as substitutes for conventional measuring instruments. These tools offer advantages like ease of use and visual analysis (Anggraini et al., 2024; Aulliyah et al., 2023; Laili & Ishafit, 2023). Furthermore, related research supports the effectiveness of virtual and digital labs in improving students' conceptual understanding and practical attitudes, even when statistical differences are not always observed in learning achievement (Alsharif, 2023; Hamed & Aljanazrah, 2020).

Despite these various studies, a clear gap remains: Research that specifically compares the effectiveness of the Soundcard Oscilloscope against a conventional oscilloscope across both open and closed resonance tubes materials is still limited. Therefore, this study seeks to fill this gap by evaluating the comparative effectiveness of these two tools in enhancing the understanding of resonance tubes concepts. This research is expected to make a significant contribution to the development of effective, innovative, and cost-efficient physics learning.

## RESEARCH METHODS

This study employed a quantitative approach with a quasi-experimental design using the Nonequivalent Control Group Design (Sugiyono, 2023). This design was necessary because random assignment was not feasible under the school's natural conditions, while still allowing the determination of the treatment's effect on learning outcomes. The research was conducted at SMA Negeri 1 Sendawar, involving eleventh-grade students selected through purposive sampling based on comparable academic characteristics. The sample comprised two intact classes: the Experimental Group (Class XI-1, $n = 32$), treated using the Soundcard Oscilloscope V1.47, and the Control Group (Class XI-3, $n = 33$), treated using a conventional oscilloscope. Data collection involved administering a pre-test and a post-test to both groups to measure the primary dependent variable: student learning outcomes on the resonance tube topic.

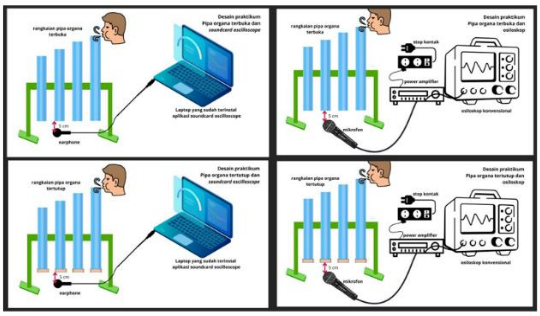

**Figure 1.** Experimental setup of the resonance tubes practicum using Soundcard Oscilloscope and conventional Oscilloscope.

The main research instrument was a learning outcomes test consisting of 20 multiple-choice questions adapted from a reliable physics textbook (Erlangga, 2022). The instrument’s content validity was confirmed by expert judgment (average score 4.61, categorized as very valid), and its empirical validity was confirmed using Pearson correlation analysis ($r_{count} > r_{table} = 0.334$). The test demonstrated very high reliability (coefficient 0.812) confirmed by the Kuder–Richardson 20 (KR-20) formula (Yusrizal, 2016). The treatment distinction and student engagement during the intervention were verified and documented (as shown in Figure 1 and Figure 2).

Figure 2. Students conducting organ pipe experiments in the classroom

Data analysis was performed using SPSS software. Prior to inferential testing, data were subjected to prerequisite tests for normality (Shapiro–Wilk) and homogeneity (Levene's test) (Ramadhani & Bina, 2021; Aminoto & Agustina, 2020). As the data did not meet normality assumptions, non-parametric statistics were employed. Descriptive statistics, including the Normalized Gain (N-Gain) (Hake, 1998), were calculated to assess practical effectiveness. For inferential testing, the Wilcoxon Signed Rank Test (Sugiyono, 2024) was used to examine within-group differences, and the Mann–Whitney U Test (Sugiyarto, 2021) was used to examine between-group differences in post-test performance.

## RESULTS AND DISCUSSION

### Results

This section presents the results of the data analysis conducted using descriptive statistics, N-Gain analysis, and non-parametric inferential tests (Wilcoxon Signed Rank Test and Mann–Whitney U Test). The findings address the two research questions regarding the effectiveness of the Soundcard Oscilloscope in improving students' learning outcomes.

### Descriptive Statistics Analysis

Descriptive analysis was carried out to examine students' initial (pre-test) and final (post-test) learning outcomes in both groups. N-Gain scores were calculated to assess the magnitude of improvement.

**Table 1**. Descriptive statistics of student learning outcomes

| Group | (*N*) | Pre-test (*M*) | Post-test (*M*) | N-Gain Score (*M*) |
|---|---|---|---|---|
| Experimental (Soundcard) | 32 | 62.81 | 74.38 | 0.095 |
| Control (Conventional) | 33 | 69.70 | 74.55 | -0.262 |

Note: *M* = Mean

The experimental group's mean score increased from 62.81 to 74.38, yielding an N-Gain of 0.095 (categorized as *low*; Hake, 1998). In contrast, the control group showed a negative N-Gain (–0.262), indicating a decline in post-test performance relative to pre-test results. This suggests that the conventional oscilloscope was less effective in supporting conceptual learning on the resonance tube topic.

### Inferential Hypothesis

Inferential tests were performed to examine within-group improvements and between-group differences.

**Table 2.** Results of within-group comparison (Wilcoxon Signed Rank Test)

| Group | *N* | *Z*-Test Score | *p*-value | Hypothesis Decision |
|---|---|---|---|---|
| Experimental (Soundcard) | 32 | -2.960 | 0.003 | Significant Difference Found |

| | | | | |
|---|---|---|---|---|
| Control (Conventional) | 33 | -1.677 | 0.094 | No Significant Difference Found |

For the experimental group, $p = 0.003 < 0.05$, indicating a significant improvement from pre-test to post-test. This confirms that the use of the Soundcard Oscilloscope positively influenced students' learning outcomes. In contrast, the control group ($p = 0.094 > 0.05$) showed no significant improvement, indicating that the conventional oscilloscope did not lead to measurable learning gains.

**Table 3.** Results of Between-Group Comparison (Mann–Whitney U Test)

| Comparative Test | *N* | *U*-Test Score | *p*-value (Asymp. Sig.) | Hypothesis Decision |
|---|---|---|---|---|
| Experimental vs. Control | 65 | 516.500 | 0.873 | No Significant Difference Found |

The Mann–Whitney U Test yielded a *p*-value of 0.873 (> 0.05), indicating no statistically significant difference between the post-test scores of the experimental and control groups. This suggests that although the Soundcard Oscilloscope improved learning within the experimental group, its overall effect was not significantly greater than that of the conventional oscilloscope when comparing the two groups' final performance.

## Discussion

This discussion integrates the statistical findings (Tables 1–3) with relevant learning theories and previous research to address the main research questions and explain the observed outcomes. The discussion is organized into four parts: the internal effectiveness of the Soundcard Oscilloscope, the performance of the conventional oscilloscope, a comparison of statistical and pedagogical perspectives, and the study's limitations and recommendations.

### Internal Effectiveness of the Soundcard Oscilloscope

The Wilcoxon test results confirmed that the Soundcard Oscilloscope was internally effective in enhancing students' learning outcomes ($p = 0.003$). This effectiveness aligns with Kolb's experiential learning theory (Danim, 2024), which emphasizes the importance of direct experience in conceptual development, as well as with frameworks of technology-enhanced learning that highlight the role of real-time visualization in supporting conceptual understanding. The utilization of computers as a practicum medium to support enhanced learning outcomes and student comprehension aligns with research by Azar and Aydın Şengüleç (2011), whose findings indicate that computer-assisted learning methods exert a positive impact on student achievement. This evidence is further reinforced by Ojo and Owolabi (2020), who demonstrated that virtual-based instructional strategies significantly improve learning outcomes in science practicals. Similarly, Papalazarou et al. (2024) emphasized that the integration of virtual experiments within inquiry-based models optimizes conceptual understanding, which directly leads to strengthened learning gains.

The Soundcard Oscilloscope transforms a standard PC into an accessible measuring instrument capable of visualizing sound waves in real time. This visualization bridges the gap between abstract wave theory and observable resonance tube phenomena, allowing students to better understand the underlying physics. These findings are consistent with previous research by Susanti and Ishafit (2025), who also reported significant learning gains through the use of similar digital tools. Furthermore, the integration of computer-based practicum media creates a more interactive and modern learning environment, which contributes to improved learning outcomes.

**Limitations of the Conventional Oscilloscope**

The control group showed no statistically significant improvement ($p$ = 0.094) and even produced a negative N-Gain (–0.262). This finding reinforces the study's initial premise regarding laboratory facility limitations in many schools. Conventional oscilloscopes often require complex calibration and relatively high technical skills to operate. As highlighted by Wild and Swan (2011), determining the period and waveform remains a primary difficulty in using analog oscilloscopes. In schools with limited resources, older or malfunctioning equipment and restricted practicum time may lead students to spend more time troubleshooting the instrument than engaging in meaningful data collection and analysis. As a result, learning experiences may become fragmented, leading to suboptimal learning outcomes and, in this case, a negative N-Gain.

**Statistical and Pedagogical Implications**

The Mann–Whitney U Test indicated no statistically significant difference between the post-test scores of the two groups ($p$ = 0.873). However, this statistical finding reveals an important distinction between statistical equivalence and pedagogical effectiveness when interpreted alongside the N-Gain results:

a. Critical Gap: Although both groups achieved similar post-test scores, the experimental group showed significant internal improvement ($p$ = 0.003), whereas the control group experienced a negative N-Gain (–0.262).
b. Comparative Conclusion: The Soundcard Oscilloscope facilitated significant learning improvements within the experimental group, while the conventional oscilloscope failed to do so. However, statistically, no significant difference was observed in learning outcomes between the experimental and control groups at the post-test stage. This outcome aligns with the findings of Hamed and Aljanazrah (2020), who noted that while students using virtual experiments were better prepared and completed tasks more efficiently, their final academic achievement did not differ significantly from those in conventional settings. Similar results have been reported by Ambusaidi et al. (2018), Azar and Aydın Şengüleç (2011), and Crandall et al. (2015), all of whom found that virtual and traditional laboratory approaches often yield comparable academic performance. Even though this did not translate into a statistically significant between-group difference at the post-test stage, the pedagogical impact of the Soundcard Oscilloscope was more meaningful in this resource-constrained setting.

These findings highlight the pedagogical advantages of low-cost digital tools, such as the Soundcard Oscilloscope, and support their broader adoption in schools with limited laboratory facilities to enhance students' conceptual understanding of resonance tube phenomena.

**Limitations and Recommendations**

Several limitations of this study should be acknowledged to inform the interpretation of the findings and guide future research directions. First, the sample size was relatively small and limited to two intact classes from a single school, which may limit the generalizability of the results to other contexts. Second, the duration of the intervention was relatively short, which may not fully capture the long-term effects of integrating digital oscilloscopes on students' conceptual development. Third, the study focused solely on cognitive learning outcomes measured through pre- and post-tests; other important dimensions such as students' scientific process skills, engagement, and attitudes toward technology-supported practicum activities were not examined.

Future research should involve larger and more diverse samples, extend the duration of interventions, and employ mixed-method approaches that examine not only cognitive outcomes but also affective and process-oriented variables. Comparative studies in different school contexts, including urban and rural settings, are also recommended to explore the scalability and adaptability of low-cost digital tools such as the Soundcard Oscilloscope in diverse educational environments.

## CONCLUSION

This study concludes that the Soundcard Oscilloscope V1.47 application represents a pedagogically advantageous and cost-effective alternative for improving physics learning outcomes, particularly in schools with limited laboratory resources. Students in the experimental group achieved statistically significant gains, while the control group exhibited no meaningful improvement and even a decline in average performance. Although the N-Gain achieved by the experimental group was modest, these findings underscore the tool's capacity to produce positive learning outcomes in contexts where conventional methods proved less effective.

From a scientific perspective, this study offers new insights by directly comparing digital and conventional oscilloscopes in the teaching of open- and closed-end resonance tubes, an area that remains underexplored in physics education research. A key finding is that the Soundcard Oscilloscope functions as a robust and practical substitute for conventional instruments in resource-constrained environments. Its success in preventing performance decline and generating internal learning gains questions the long-held assumption that conventional laboratory equipment is indispensable, thereby emphasizing the value of context-specific digital innovations.

These findings carry important implications for science education policy and practice. They validate the integration of low-cost digital tools as a viable strategy for addressing laboratory equipment shortages, thereby expanding opportunities for hands-on experimentation in schools with limited resources. Future research should further refine the use of such tools by incorporating advanced data analysis features, such as quality factor measurements and effective length calculations (Iskandar & Pramudya, 2025) to enhance experimental accuracy. Additionally, longitudinal studies are recommended to investigate the long-term effects of digital practicum media on students' conceptual understanding and motivation.

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