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The Effect of the Collaborative Jire Learning Model Assisted by Virtual Laboratory Simulations on Junior High School Students' Learning Outcomes in Dynamic Electricity

Lukman Hulawa, Nova Elysia Ntobuo, Tirtawaty Abdjul

Pascasarjana, Universitas Negeri Gorontalo

ABSTRACT

Improving the quality of science education requires innovative instructional approaches that actively engage students in the learning process. This study aimed to examine the effect of the Collaborative JIRE Learning Model assisted by Virtual Laboratory simulations on student learning outcomes in the topic of dynamic electricity. Grounded in collaborative pedagogy and technology integration, the research addresses the need for more interactive and student-centered science instruction at the junior high school level. A quantitative, pre-experimental design was employed, using a one-group pretest–posttest approach involving 96 ninth-grade students from two public junior high schools. Data were collected through validated cognitive assessments administered before and after the learning intervention. Statistical analyses included tests of normality, t-tests, ANOVA, and regression using SPSS software. The results showed a significant improvement in students' academic performance following the intervention. The regression analysis revealed that the model explained 68% of the variance in learning outcomes, with a strong positive correlation between the instructional approach and student achievement. The findings suggest that combining structured peer collaboration with interactive virtual simulations enhances conceptual understanding and engagement in science learning.

This study contributes to the growing body of knowledge on digital and collaborative instruction, offering practical implications for teaching practices and future research in science education reform.

Keyword: *Virtual Laboratory, Collaborative Learning, Student Learning Outcomes*

Introduction

Improving the quality of education remains a central focus of national development agendas, particularly in emerging countries like Indonesia. The enhancement of teaching and learning processes is seen as critical for fostering sustainable and inclusive development. The Indonesian government has actively pursued reforms through curriculum innovation, infrastructure development, teacher training, and the integration of educational technology. These efforts aim to address disparities in educational access and quality, particularly between urban and rural areas. According to Ntobuo (2018:1), the successful organization of educational delivery requires optimal execution, suggesting that the structural and pedagogical aspects of teaching must be addressed in a balanced and integrated manner. In parallel, global shifts toward digital transformation and the 21st-century learning framework further underscore the necessity for adaptive and student-centered learning approaches.

Teachers' instructional competence is a cornerstone of educational quality. An effective teacher does not merely transmit knowledge but creates a dynamic and inclusive learning environment where students are engaged cognitively, emotionally, and socially. Such instructional ability encompasses mastery of subject matter, clarity in delivery, adaptive pedagogy, and constructive feedback mechanisms. Teachers must also manage classroom dynamics and foster active participation. However, despite these ideals, various systemic barriers continue to constrain teachers' ability to plan and implement effective learning strategies. Limited time, insufficient resources, inadequate access to professional development, and the diversity of learners' needs often hinder lesson planning (Ntobuo, 2018:1). These barriers are well-documented in educational literature, including by Schunk (2001) and Zimmerman (2002), who emphasize the need for supportive learning environments and self-regulation in promoting student achievement.

A common issue observed in Indonesian middle schools, particularly in science education, is the predominance of teacher-centered instruction that overlooks the importance of student engagement and scientific process skills. Many educators focus heavily on content transmission and exam outcomes rather than cultivating inquiry, critical thinking, and collaborative problem-solving. Science education, in its ideal form, integrates process, product, and scientific attitude (Umar et al., 2011:6). The scientific process element includes formulating hypotheses, designing experiments, collecting and analyzing data, and drawing conclusions. Unfortunately, limitations in lab resources and pedagogical strategies often lead to underdeveloped scientific reasoning among students. These challenges call for innovative pedagogical models that can foster deeper conceptual understanding and promote learner autonomy.

In recent decades, technological advancement has reshaped how students interact with content and each other. Educational technology, including virtual simulations and mobile applications, has increased access to learning materials and facilitated remote learning. However, the benefits of technology come with trade-offs. Excessive reliance on devices may result in reduced face-to-face interaction, distraction, and even addiction (Simamora in Fahrozi et al., 2023:131; Wijanarko, 2016:9). Smartphones, while often viewed as a source of distraction, can also be recontextualized as tools for active learning. The key lies in adopting guided, structured, and collaborative digital learning environments that align with pedagogical goals.

In light of these developments, educational practitioners and researchers have begun to explore the integration of collaborative learning models with digital platforms. One such model is the Collaborative JIRE Learning Model, which emphasizes cooperative learning through the division of learners into "home groups" and "expert groups." The JIRE model builds upon the classic jigsaw model by incorporating deeper collaborative structures and emphasizing both cognitive and social development (Ntobuo, 2018:2). Although initially validated in higher education contexts, recent studies indicate that the model is equally effective in senior high school settings (Ntobuo, 2021:131–137). The model allows learners to interact according to their respective competencies, thereby fostering mutual learning and knowledge co-construction. Its implementation addresses several pedagogical challenges, including student disengagement and lack of peer interaction.

To further enhance this model's effectiveness, educators have integrated it with Virtual Laboratories. Virtual labs offer cost-effective, safe, and flexible alternatives to physical labs, particularly in resource-limited settings. As Hughes (2005) and Hughes & Stewart (2004) note, virtual labs allow students to conduct complex experiments involving abstract scientific concepts without the risks and costs associated with real-world laboratories. Nikolopoulou & Gialamas (2020) emphasize that such tools significantly improve learning participation and conceptual understanding, especially when students are given the autonomy to engage in simulations repetitively and at their own pace. These platforms also align with the behavioral tendencies of digital-native students, who are more responsive to audio-visual content and interactive learning environments.

The relevance of using mobile-based virtual labs becomes more apparent in schools where access to physical science equipment is constrained. In such contexts, a blend of collaborative learning and virtual laboratory usage can transform learning experiences. When teachers leverage students' natural inclination toward smartphone usage by integrating it with structured scientific simulations, they not only enhance engagement but also promote deeper conceptual understanding (Ntobuo, 2018:183). Empirical evidence suggests that these methods improve students' cognitive outcomes and foster independence in learning (Kurnia Muhajarah & Sulthon, 2020; Garris, Ahlers, & Driskell, 2002). Nevertheless, challenges in managing collaborative learning groups—such as uneven task completion rates and difficulties in coordinating expert group discussions—must be mitigated through effective classroom management and scaffolding strategies.

Several previous studies have explored the efficacy of collaborative learning models and virtual laboratories individually. Ntobuo (2018; 2023) demonstrated that the JIRE model, when combined with Android-based platforms, significantly enhanced student performance in momentum and impulse materials at the high school level. Hughes (2005) and Spector (2014) supported the notion that integrating educational technology can deepen student understanding, increase retention, and develop essential digital literacy skills. Yet, a notable research gap remains: there is a lack of empirical studies examining the combined application of the JIRE model and virtual laboratories at the junior high school level, particularly in the context of physics education. Addressing this gap is crucial given the cognitive demands of topics like dynamic electricity, which require both abstract reasoning and hands-on experimentation.

This study aims to investigate the influence of the Collaborative JIRE Learning Model assisted by Virtual Laboratory simulations on junior high school students' learning outcomes in the topic of dynamic electricity. Additionally, it explores the role of learner autonomy as a moderating variable. The novelty of this study lies in its integration of two pedagogical innovations—collaborative learning and virtual laboratories—at the middle school level, a context in which such integration is underexplored. The research contributes to a growing body of literature on digital pedagogy and science education, offering practical insights for improving instructional quality in resource-limited environments. Furthermore, the study's findings may inform the development of scalable, technology-enhanced learning strategies that align with national educational priorities and the needs of 21st-century learners.

Methodology

This study adopted a quantitative approach using a pre-experimental research design to investigate the effect of the Collaborative JIRE Learning Model assisted by a Virtual Laboratory on students' learning outcomes in the topic of dynamic electricity. The research design employed was the One-Group Pretest–Posttest model, as outlined by Sugiyono (2016:110), which involved administering a pretest to establish baseline student performance, followed by the application of the treatment, and subsequently a posttest to measure learning gains. The research was conducted over a two-month period during the even semester of the 2024/2025 academic year at SMP Negeri 1 Tolangohula in Gorontalo Regency and SMP Negeri 8 Paguyaman in Boalemo Regency. The study population included ninth-grade students from all public junior high schools in the two districts, with a purposive sample of 96 students selected from four classes—two experimental and two replication groups.

The independent variable in this study was the Collaborative JIRE Learning Model integrated with Virtual Laboratory simulations (X_1), while the dependent variable was student learning outcomes (Y), measured according to the revised Bloom's taxonomy levels—remembering, understanding, applying, analyzing, evaluating, and creating (Krathwohl & Anderson). The instruments used included a structured cognitive test for assessing learning outcomes, which was validated through expert judgment involving five specialists in physics education (Arikunto in Riduwan, 2004:97). Data collection was conducted through pretests and posttests, and the results were analyzed using SPSS version 20. Statistical analyses included the Kolmogorov–Smirnov test for normality, Levene's test for homogeneity (Machali, 2017:37), and both t-tests and ANOVA to determine the significance of the treatment effect. A significance level of 0.05 was used to test the hypothesis, and the coefficient of determination (R^2) was calculated to assess the extent to which the model explained the variance in student learning outcomes. The study maintained ethical standards by ensuring informed consent and confidentiality for all participants. Based on this design, the research aimed to determine whether the Collaborative JIRE Learning Model, when supported by digital laboratory tools, significantly improved student academic performance in the subject of dynamic electricity.

Results and Discussion

This study was conducted to examine the impact of the Collaborative JIRE Learning Model supported by Virtual Laboratory simulations on the learning outcomes of junior high school students in the topic of dynamic electricity. Data were collected using a structured cognitive assessment administered before and after the implementation of the learning intervention. To ensure the accuracy and validity of findings, the research involved a series of statistical procedures, including instrument validation, assumption testing (normality and homogeneity), and inferential analysis (t-test, ANOVA, and regression).

The cognitive test instrument was validated through expert judgment by five subject matter experts in physics education, ensuring that the test accurately captured the constructs intended for measurement (Arikunto in Riduwan, 2004:97). The construct validity process confirmed that the assessment items were appropriately aligned with Bloom's revised taxonomy, encompassing six cognitive domains: remembering, understanding, applying, analyzing, evaluating, and creating. Given the use of expert validation, the study did not include a separate test for reliability, following Sudjana's (2006:16) guidance on reliability as consistency under expert validation.

Data Normality and Homogeneity Tests

Before proceeding to hypothesis testing, it was essential to examine whether the data fulfilled the assumptions of normality and homogeneity. The normality of the dataset was tested using the Kolmogorov–Smirnov method via SPSS version 20. For the variable measuring the effect of the Collaborative JIRE Model with Virtual Lab (X_1) on learning outcomes (Y), the significance value was 0.611, which is greater than the threshold of 0.05. This indicated that the data were normally distributed. Similarly, the test for the independence variable of student self-regulation (X_2) yielded a significance value of 0.059, further confirming that the assumption of normal distribution was met (Machali, 2017:37).

The homogeneity of variance between groups was also assessed using Levene's test, ensuring that both the experimental and replication groups derived from populations with similar variance characteristics. The findings from this test supported the continuation of further parametric analysis.

Inferential Analysis of the Treatment Effect

t-Test for Hypothesis Testing

To assess the primary research hypothesis—that the Collaborative JIRE Learning Model assisted by Virtual Laboratory simulations positively affects student learning outcomes—a simple linear regression analysis was performed, followed by a t-test to evaluate statistical significance. The resulting regression equation was:

$Y = 118.11 + 3.564X$

This model indicates that for every unit increase in the implementation of the Collaborative JIRE Model with Virtual Laboratory support, student learning outcomes increased by an average of 3.564 points. The t-statistic obtained was 9.82, which exceeded the critical t-value of 2.000 ($\alpha = 0.05$, df = 95), and the corresponding p-value was 0.000. Given that the p-value was significantly below the 0.05 threshold, the null hypothesis (H_0: $\beta = 0$) was rejected, confirming the presence of a statistically significant positive relationship between the instructional model and student learning outcomes.

These findings are in alignment with previous research by Ntobuo (2018), which demonstrated that the integration of collaborative models with digital tools leads to improved academic performance. Additionally, the positive effect size of the beta coefficient (3.564) suggests a moderately strong practical influence of the intervention, reinforcing its potential effectiveness in junior high school contexts.

Paired Samples t-Test for Pre- and Post-Test Differences

To further validate the effect of the treatment, a paired samples t-test was conducted to compare pretest and posttest scores. The mean difference was substantial, and the t-value of -21.257 confirmed a statistically significant increase in student performance after the intervention ($p = 0.000 < 0.05$). Despite the negative t-value indicating a reversal in score direction (posttest > pretest), the magnitude of change suggests that the instructional model had a meaningful impact.

ANOVA (F-Test) for Model Significance

The F-test was applied to examine whether the variation in student learning outcomes could be attributed significantly to the independent variable. The ANOVA results yielded an F-value of 97.677, which far exceeded the critical F-table value of 4.08 (df = 1, 94; $\alpha = 0.05$). The corresponding p-value was 0.000, affirming that the regression model as a whole was statistically significant. These results corroborate the outcomes of the t-tests and highlight the robustness of the instructional intervention's influence on academic achievement.

Coefficient of Determination (R^2)

The model summary revealed an R^2 value of 0.680, indicating that approximately 68% of the variance in students' learning outcomes could be explained by the application of the Collaborative JIRE Model with Virtual Laboratory simulations. This is a substantial proportion, suggesting that the intervention was highly effective in shaping students' academic performance in dynamic electricity. The remaining 32% of variance is likely attributable to other variables not examined in this study, such as prior knowledge, classroom environment, teacher experience, or individual learning styles.

Interpretation and Discussion of Findings

The findings of this study contribute to the growing body of literature advocating for the integration of collaborative learning strategies with technology-assisted instruction, especially in the domain of science education. The Collaborative JIRE Model, an enhanced form of the classic jigsaw model, promotes interaction among students through structured roles in both home and expert groups (Ntobuo, 2018:2). When combined with the use of Virtual Laboratory simulations, the model allows for greater engagement, deeper conceptual understanding, and enhanced student autonomy.

This integration is consistent with the theoretical perspectives of constructivist learning, which emphasize active participation and knowledge construction through social interaction and meaningful context (Spector, 2014; Hughes & Stewart, 2004). Virtual Laboratories, in particular, provide learners with the opportunity to explore scientific phenomena that may not be feasible in traditional classrooms due to financial or safety constraints (Hughes, 2005; Tatli & Ayas, 2012). The flexibility offered by these platforms—allowing students to learn independently, repeat simulations, and control variables—supports personalized and inquiry-based learning (Nikolopoulou & Gialamas, 2020).

Furthermore, the significant learning gains observed in this study align with Garris, Ahlers, and Driskell's (2002) findings, which emphasize that interactivity in digital learning environments enhances both engagement and retention. By embedding learning in a digital medium that is familiar and appealing to students—particularly mobile-based applications—the instructional model capitalizes on students' existing behaviors while redirecting them toward academic goals (Fahrozi et al., 2023; Wijanarko, 2016).

However, while the results are encouraging, several limitations must be considered. The one-group pretest-posttest design, although suitable for initial exploration, lacks a control group, which limits the ability to fully isolate the effect of the treatment from other confounding factors. Future studies should consider employing randomized controlled trials or quasi-experimental designs to strengthen causal claims. Additionally, the study relied on a single subject area and topic; extending the research to other science topics or disciplines could further validate the generalizability of the findings.

From a practical standpoint, this study offers several implications for educators and policymakers. First, the Collaborative JIRE Model demonstrates the importance of structured, student-centered learning environments that encourage peer teaching and knowledge sharing. Second, the inclusion of Virtual Laboratory simulations not only mitigates logistical barriers but also enhances students' ability to visualize and experiment with abstract scientific concepts. Finally, the strong statistical significance and explanatory power of the model suggest that such innovations could be scaled and adapted to other educational settings, particularly in under-resourced schools.

Educators should be provided with targeted professional development to effectively implement collaborative strategies and integrate virtual tools into their instruction. Furthermore, curricular frameworks should be adapted to support such blended learning models, ensuring that they are not only technologically sound but also pedagogically robust.

Conclusion

This study demonstrated that the implementation of the Collaborative JIRE Learning Model assisted by Virtual Laboratory simulations significantly improves student learning outcomes in the topic of dynamic electricity. Statistical analyses confirmed a strong and positive relationship, with the instructional model accounting for 68% of the variance in student achievement. The combination of structured peer collaboration and interactive digital simulations proved effective in fostering deeper conceptual understanding and student engagement.

These findings highlight the pedagogical value of integrating cooperative learning strategies with technology-enhanced instruction, especially in science education where abstract concepts often require visual and experiential support. This study contributes to existing literature by extending the application of the JIRE model—previously tested in higher and secondary education—to junior high school settings, addressing a critical gap in empirical research.

The implications for practice include the need to support teachers through training in collaborative pedagogy and digital tools. For future research, exploring the model's impact across different scientific domains, age groups, or in comparison with traditional methods will provide further insights. Overall, this study reinforces the importance of innovative, student-centered learning models in improving educational outcomes and preparing students for a technologically advanced academic environment.

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