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Improving Learning Outcomes in Electrical Circuits Through STAD Cooperative Learning with Structured Tasks

Faried Wajdi

Faculty of Engineering, Universitas Negeri Jakarta, Jl. Rawamangun Muka, Jakarta 13220, Indonesia

✉: Bigfaried.33@gmail.com

Abstract

This study aims to evaluate the effectiveness of the STAD (Student Teams-Achievement Divisions) cooperative learning model in enhancing students' understanding of electrical circuit concepts in the Electrical Engineering Education Study Program. The research method employed was an experimental design with a pretest-posttest approach involving 56 respondents divided into two groups: an experimental group applying the STAD model and a control group using conventional learning methods. Data were collected through pretests and posttests and analyzed using Jamovi 2022 software. The results indicate that the average score of the experimental group increased from 8.96 in the pretest to 13.7 in the posttest, with a significant effect size of -4.05. These findings suggest that the implementation of the STAD model not only improves student learning outcomes but also fosters collaboration and interaction among students. Therefore, it is recommended that the STAD cooperative learning model with structured tasks be more widely adopted to enhance conceptual understanding of Electrical Circuits.

Keywords: cooperative learning, STAD, electrical circuits, learning outcomes, engineering education

INTRODUCTION

Electrical circuits represent a combination of physics and mathematics that often causes concern among high school students. As they transition to higher education, the complexity of this material increases, adding to the challenges they face. To understand electrical circuits, students need a deep comprehension of physical principles, the application of complex mathematical formulas, and the ability to solve abstract problems that arise in the context of electrical circuits. One common issue is students' lack of motivation and engagement in the learning process, which can hinder their understanding of the material (Marcelina & Hartanto, 2021). Other contributing factors are the less contextual learning approach and the minimal use of interactive media or tools, making it difficult for students to connect theory with real applications (Liu et al., 2022). More innovative and interesting learning methods, such as simulations, direct experiments, and problem-solving-based approaches, are needed to improve students' understanding and interest in electrical circuits (Siong et al., 2023; May et al., 2022; Malik et al., 2020).

In the Electrical Engineering program, students are expected to apply key concepts in learning about electrical circuits, such as Ohm's Law, nodal analysis, and mesh analysis. They must also be capable of designing efficient electrical circuits. The STAD cooperative learning model can improve structured learning to overcome these problems (Liu & Yoon, 2024; Wahyudi et al., 2020; Yoon et al., 2024). This model encourages student collaboration (Tcheslavski et al., 2024), increases motivation, and allows them to learn from one another within groups (Hsiung, 2010, 2011). By applying this model, students learn from the material presented by the instructor and their peers (Harvie et al., 2024; Manunure et al., 2020). This can help improve their understanding of electrical circuit material and enhance their social skills (McVey et al., 2019).

STAD cooperative learning is expected to create a more interactive learning environment, supporting students' holistic development. Structured learning is conducted through the systematic organization of material and learning activities (Burgess et al., 2019; McVey et al., 2019; Watt et al., 2011). Subsequently, students are assigned to create summaries to enhance their understanding of the material (Jama & Alnefaie, 2022; Mohamed et al., 2023). These summaries are based on the results of class discussions (Dowell et al., 2014) and are supplemented with questions and answers. More capable students are expected to assist their peers in solving problems that some may find challenging in front of the class (Azemi & Toto, 2012; DePiero et al., 2017; Harb et al., 2015; Hite et al., 2017; Widodo et al., 2023).

Additionally, this model can enhance students' self-confidence as they feel more motivated and supported by their peers (Marar et al., 2022). Through collaboration, they also learn to appreciate others' opinions and work together to complete academic tasks (Kanchana & Cherukuri, 2024; Koe et al., 2020; Pazos et al., 2019). Thus, not only are their academic abilities sharpened, but their social skills are also developed, which will aid their future success. Furthermore, this model can improve communication skills, essential in various aspects of their daily lives (Czyzak, 2020; Frey, 2005; Garner, 2023; Yelsma, 2023). All these competencies are crucial for students entering the field of electrical engineering workforce, as they will facilitate their ability to face professional challenges in the future (O'Connell, 2015).

Despite numerous studies on electrical circuit learning, few have explored the application of the STAD cooperative learning model in this context. Previous research has focused on traditional teaching methods or individual approaches, thus neglecting social interaction and collaboration among students. Currently, many studies have shown that cooperative learning can enhance learning outcomes (Kalaian et al., 2018; Tahir et al., 2011; Travassos Valdez et al., 2009, 2010). However, the specific implementation of the STAD model in electrical circuit learning remains rare. This study aims to fill this gap by exploring the effectiveness of the STAD model in improving students' understanding of electrical circuits. The novelty of this research lies in applying the STAD cooperative learning model in the context of electrical circuit learning, which has not been extensively studied. By implementing this model, it is expected that students can be more active in the learning process, increase motivation, and gain a better understanding of the concept of electrical circuits through discussions and team-based learning (Karmila & Efrizon, 2022; Supratiningsih et al., 2021). This research will also integrate structured assignments with a collaborative approach, providing a new contribution to teaching methods in the field of electrical engineering.

The objective of this study is to evaluate the effectiveness of the STAD cooperative learning model in enhancing students' understanding of electrical circuit concepts, as well as to increase student motivation and engagement in the learning process. The urgency of this research lies in the need to improve the quality of electrical circuit learning for students. By implementing a more interactive and collaborative learning model, it is hoped that students will better grasp complex concepts, preparing them for challenges in higher education and the workforce in electrical engineering. This study also aims to provide insights for educators in designing more effective and engaging teaching methods.

METHODS

This study employs an experimental design with two groups: an experimental group applying the STAD (Student Teams-Achievement Divisions) cooperative learning model and a control group utilizing conventional teaching methods. This research aims to evaluate the effectiveness of the

cooperative learning model in enhancing students' understanding of electrical circuit material in the Electrical Engineering Education Study Program during the even semester of the 2023/2024 academic year.

The research population consists of students enrolled in the Electrical Circuits course, with a sample size of 52 students divided into two groups of 26. According to Tahir et al. (2011), Travassos Valdez et al. (2009, 2010), and Kalaian et al. (2018), the use of a small sample does not diminish statistical power, and the research results remain effective in improving student learning outcomes. Group assignment was conducted randomly based on the course section numbers registered in the academic system (SIKAD) of Universitas Negeri Jakarta. The experimental group was formed heterogeneously based on academic ability (mathematics and English diploma scores) and gender, while the class instructor formed the control group as usual. This grouping ensured that both groups had balanced characteristics before the intervention.

Before the intervention, both groups underwent a pretest to assess students' initial abilities. The pretest consisted of 30 multiple-choice questions with five options, validated by subject matter experts. The validation scores provided by the experts were as follows: Expert 1 scored 0.93, Expert 2 scored 0.87, and Expert 3 scored 1.00. The average validation score from the experts was 0.93, indicating that the instrument used in this study possesses a very high level of validity. After the pretest, both groups received the same treatment in the form of structured tasks over eight weeks. These structured tasks included several activities, such as reading provided materials in PDF format, conducting group discussions in class, creating summaries, and solving problems collaboratively. The activities concluded with a joint discussion of challenging problems at the beginning of the learning process, designed to enhance student interaction and collaboration. The study groups aimed to improve social interaction, encourage cooperation, and support active learning, allowing students to assist each other and better understand concepts (Hsiung, 2010; Hsiung, 2011).

Following the intervention period, a posttest will be conducted to determine the impact of the cooperative and conventional methods on student learning outcomes in both groups. Data collected from the pretest and posttest will be analyzed to identify differences in learning outcomes within the same group before and after the intervention. Subsequently, data from both groups will be compared to ascertain the differences in learning outcomes between the experimental and control groups. The data analysis technique employed will be an independent samples t-test to assess whether there are significant differences in learning outcomes between the two groups. This t-test will be conducted at a significance level of 5% ($p = 0.05$), and all data analyses will be performed using Jamovi 2022 software.

With this systematically designed methodology, it is anticipated that this research will significantly contribute to the development of teaching methods in the field of electrical engineering and enhance students' understanding of electrical circuit material through an effective collaborative approach.

RESULTS AND DISCUSSION

This study analyzes the effects of the STAD (Student Teams-Achievement Divisions) cooperative learning model and conventional teaching methods utilizing structured tasks on students' learning outcomes in electrical circuits. The analysis was conducted by comparing pretest and posttest data to evaluate the improvement in learning outcomes within each group. This is a description of the research findings regarding both methods.

Validator Assessment Results

FIGURE 1 illustrates the validation results from experts in the field of electrical circuit learning materials. This validation process involved three experts who provided assessments of five main indicators, namely Content Relevance, Question Clarity, Relevance, Difficulty Level, and Readability. This assessment aims to ensure that the materials used in electrical circuit learning have met the expected quality standards before being applied in the teaching and learning process.

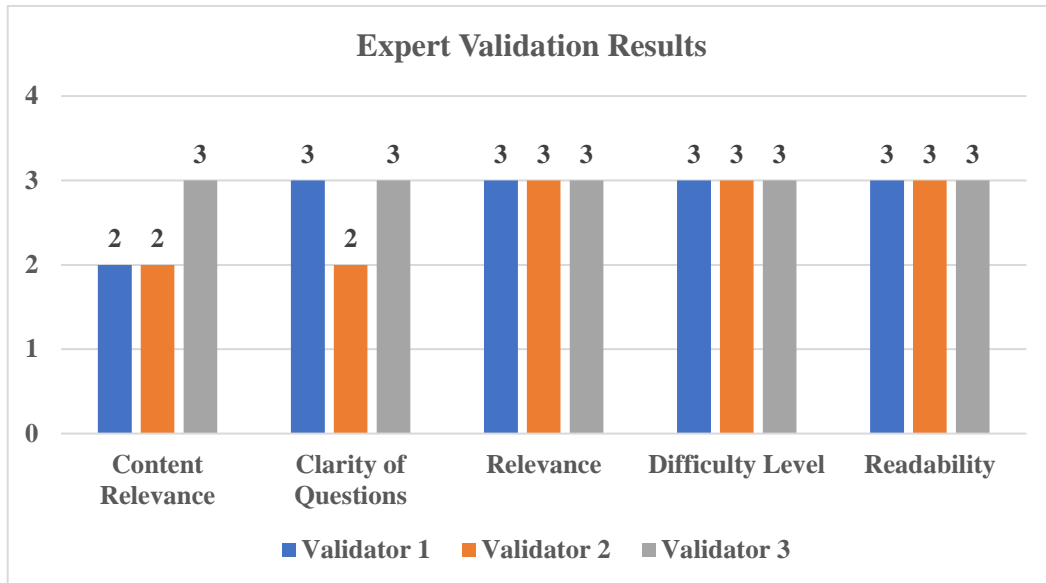


FIGURE 1. Results of assessment by validator

The expert validation results indicate that the aspects of Relevance, Difficulty Level, and Readability were rated optimally, receiving a score of 3 from all validators. This suggests that the instrument or material is considered relevant, appropriately challenging, and easy to read. However, regarding Content Relevance, Validator 1 and Validator 2 gave a score of 2, while Validator 3 gave a score of 3, indicating differences in perception regarding content suitability. Similarly, for Clarity of Questions, Validator 1 and Validator 3 rated it 3, whereas Validator 2 only gave it a 2, suggesting that some questions may still be unclear or need improvement. Therefore, although most aspects have been rated well, improvements are necessary, particularly in content relevance and question clarity, such as by making the questions more explicit and ensuring that the material used aligns with the intended objectives.

Result

Learning Outcomes in Electrical Circuits with Structured Tasks for the Experimental Group

The descriptive results of the pretest and posttest for the experimental group, utilizing the STAD cooperative learning method with structured tasks, are presented in TABLE 1.

TABLE 1. Statistical Description of Experimental Group Learning Outcomes

	Pretest	Posttest
N	26	26
Mean	8.96	13.7
Median	9.00	14.0
Std. Dev.	2.29	2.83
Minimum	5	8
Maximum	13	19

The analysis results indicate an increase in the average score from 8.96 in the pretest to 13.7 in the post-test, suggesting that the STAD cooperative learning method with structured tasks positively impacts students' learning outcomes. The increase in the median from 9.00 to 14.0 also indicates improvement. The minimum and maximum scores rose from 5 and 13 in the pretest to 8 and 19 in the post-test, reflecting enhanced performance across all student ability levels. However, the increase in standard deviation from 2.29 to 2.83 indicates more significant variability in post-test scores, meaning that some students experienced more significant improvements than others.

Learning Outcomes in Electrical Circuits with Structured Tasks for the Control Group

The descriptive results of the pretest and posttest for the control group, utilizing conventional teaching methods with structured tasks, are presented in TABLE 2.

TABLE 2. Descriptive Statistics of Learning Outcomes for the Control Group

	Pretest	Posttest
N	26	26
Mean	7.23	12.0
Median	7.00	12.0
Std. Dev.	2.34	2.37
Minimum	2	7
Maximum	12	17

The analysis results show an increase in the average score from 7.23 in the pretest to 12.0 in the posttest, indicating that conventional teaching methods also enhance learning outcomes. Nevertheless, the average and median learning outcomes for the control group remain lower than those of the experimental group. The increase in the minimum score from 2 in the pretest to 7 in the posttest and the maximum score from 12 in the pretest to 17 in the posttest demonstrates that the entire spectrum of student abilities has improved. The variation in learning outcomes remains relatively stable, with the standard deviation only slightly increasing from 2.34 to 2.37.

Statistical Analysis

Results of the Paired Samples T-Test for the Experimental Group with Structured Tasks

The results of the paired samples t-test for the pretest and posttest of the experimental group with structured tasks are presented in TABLE 3.

TABLE 3. Paired Samples T-Test Results for the Experimental Group

	Statistic	df	p	Effect Size
Pretest-Posttest	-22.0	25	< .001	-4.31

TABLE 3 presents the results of the Paired Samples T-Test for the experimental group. The obtained t-value is -20.7 with 25 degrees of freedom (*df*) and a p-value of < .001. These results indicate a highly significant difference between the pretest and posttest scores, leading to the rejection of the null hypothesis (H_0) and the acceptance of the alternative hypothesis (H_1). This implies a significant effect of implementing the STAD cooperative learning model with structured tasks on the student's learning outcomes in electrical circuits. Furthermore, the Cohen's d value of -4.05 indicates a very large effect size, reinforcing that the STAD learning method intervention not only has a significant impact but also strongly affects improving students' learning outcomes in electrical circuit material. Overall, these findings suggest that applying the STAD cooperative learning model with structured tasks effectively enhances students' understanding of electrical circuit concepts and has positive implications for teaching methods in electrical engineering.

Paired Sample T-Test Results for the Control Group

The results of the paired sample t-test for the pretest and posttest of the control group are presented in TABLE 4.

TABLE 4. Results of the Post Paired Samples T-Test for the Control Group

	Statistic	df	p	Effect Size
Pretest-Posttest	-22.0	25	< .001	-4.31

TABLE 4 presents the results of the paired sample t-test for the pretest and posttest of the control group. The obtained t-value was -22.0, with 25 degrees of freedom (*df*) and a p-value of less than 0.001. These results indicate a highly significant difference between the pretest and posttest scores, supporting the rejection of the null hypothesis (H_0) and suggesting a significant difference in the learning outcomes of students using conventional learning methods with structured tasks. Additionally, Cohen's *d* value of -4.31 indicates a very large effect size, confirming that even when conventional learning methods are applied, this intervention still substantially impacts improving student learning outcomes. Thus, the results of this analysis suggest that conventional learning methods with structured tasks effectively enhance students' understanding of the material being taught.

Although the control group demonstrated a significant increase, it is important to consider comparing the control and experimental groups utilizing the STAD cooperative learning model with structured tasks. These findings indicate that both learning methods positively affect learning outcomes; however, the difference in effectiveness between the two methods warrants further research.

Paired Sample T-Test Results for Control Group With Structured Task

The results of the t-test comparing the pretest and posttest scores between the experimental group and the control group are presented in TABLE 5 and TABLE 6.

TABLE 5. T-Test Results for Pretest Between Experimental and Control Groups

	Statistic	<i>df</i>	<i>p</i>
Experiment – Control Group	3.35	25	< .003

The pretest results presented in TABLE 5 indicate a significant difference between the experimental group and the control group, with a p-value of 0.003. The experimental group had a higher average score compared to the control group. This finding suggests that there is a difference in the initial abilities of students in the two groups prior to the intervention, supporting the research hypothesis that the experimental group has more significant potential for understanding the material.

TABLE 6. T-Test Results for Posttest Between Experimental and Control Groups

	Statistic	<i>df</i>	<i>p</i>
Experiment – Control Group	2.77	25	0.010

The posttest results in TABLE 6 show a significant difference between the experimental and control groups, with a p-value of 0.010. The average score of the experimental group was higher than that of the control group, indicating that the STAD cooperative learning method is more effective than the conventional learning method in enhancing student learning outcomes. This finding supports the alternative hypothesis (H_1), which states that applying the STAD method with structured tasks will lead to a more significant increase in student learning outcomes compared to the conventional method. Thus, these results underscore the importance of implementing more interactive and collaborative learning approaches to improve students' understanding of the subject matter in electrical circuits. Overall, this analysis demonstrates that although both groups experienced an increase in learning outcomes, the group using the STAD method achieved better results, highlighting the effectiveness of this method in the context of learning electrical circuits.

Discussion

The results of the pretest conducted on both groups indicated that the experimental group, which utilized the STAD cooperative learning model, had an average score of 8.96 (SD = 2.29), higher than the control group, which employed conventional learning methods with an average score of 7.23 (SD = 2.34). This difference was significant, with a p-value of 0.003, suggesting that the initial abilities of students in the experimental group were superior to those in the control group. One possible reason for

this difference is that registration in SIAKAD is uncontrolled, allowing students to register online. This may lead to varying student characteristics; some students may approach the test more seriously than others. Research by John Hattie (2008) shows that student characteristics significantly impact learning outcomes. Therefore, the higher pretest results of the experimental group can be understood in this context.

Furthermore, the posttest results revealed that the experimental group also achieved a higher average score than the control group, with a p-value of 0.010. This finding supports the alternative hypothesis (H_1), which posits that applying the STAD method with structured tasks will lead to a more significant increase in student learning outcomes compared to conventional methods. This aligns with Slavin's (2005) research, emphasizing that a supportive learning environment can enhance student learning outcomes.

Further analysis indicates that applying the STAD cooperative learning model with structured tasks significantly affects student learning outcomes in electrical circuit material, with a t-value of -20.7 and $p < 0.001$. Previous studies have also demonstrated that this learning model improves learning outcomes and enhances student motivation and engagement (Damayanti & Nuzuli, 2023; Jayaram, 2013; Johnson, 1999; Xie, 2014). Additionally, a cooperative learning environment encourages group members to engage in meaningful conversations and improves communication skills (Budiono et al., 2020; Han, 2015; Lozano-Palacio et al., 2024; Ismail et al., 2019). Moreover, this model contributes to the social development of students (Han, 2015). Cohen (1988) states that a Cohen's d value above 0.8 is considered a large effect. The calculated Cohen's d value of -4.05 indicates that the application of cooperative learning methods with structured tasks significantly influences the changes in students' electrical circuit learning outcomes.

CONCLUSION

This study's results indicate that applying the STAD cooperative learning model with structured tasks significantly improves student learning outcomes in electrical circuit material. This model enhances learning outcomes and fosters collaboration and interaction among students, which are crucial in electrical engineering education.

The implications of this study confirm that interactive and collaborative learning methods can increase student motivation and engagement, preparing them to face challenges in higher education and the workforce. Therefore, it is recommended that educators consider incorporating cooperative learning models into the teaching and learning process to improve student understanding and engagement.

However, this study has limitations related to the small sample size, with only 52 respondents divided into two groups. These results may not fully represent the broader population. Therefore, further research with more extensive and diverse samples is needed to confirm these findings and explore the effectiveness of the STAD model in different learning contexts.

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