Visualizing complexity: an interactive web tool for mastering transformer equivalent circuits in engineering education

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ABSTRACT

The analysis of transformer equivalent circuits remains a conceptually challenging topic in undergraduate electrical engineering, where students often struggle to connect abstract mathematical models with empirical data from open-circuit and short-circuit tests. This study aims to bridge this pedagogical gap by designing, developing, and evaluating a unified, web-based "transformer equivalent circuit and analysis tool" that facilitates real-time visualization of circuit parameters and voltage regulation. The research design employed an exploratory mixed-methods approach, utilizing a constructivist learning framework. The tool was integrated into an undergraduate curriculum where 25 electrical engineering students utilized the platform to process laboratory data. Evaluation was conducted using a structured questionnaire (Cronbach's α=0.92) that assessed usability, conceptual understanding, and feature effectiveness, alongside qualitative feedback. Results indicated high perceived usability and a significant consensus that the tool clarified the relationship between theory and application. The implications of this study suggest that accessible, browser-based simulations serve as powerful supplementary resources that reduce extraneous cognitive load. By automating complex calculations and providing dynamic visual feedback, these tools effectively foster active learning and confidence in mastering complex engineering subjects, eliminating the barriers associated with traditional, high-complexity simulation software.

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1. INTRODUCTION

The study of transformers is a cornerstone of electrical engineering, linking fundamental circuit theory to practical power system applications. Despite their importance, students often struggle to grasp transformer operation, particularly in connecting theoretical equivalent circuit models with laboratory measurements. Traditional teaching methods—relying on manual calculations, static phasor diagrams, and using complex platforms like MATLAB/Simulink—frequently fail to convey the dynamic relationships among voltage, current, losses, and magnetic coupling. Consequently, learners have difficulty visualizing how experimental data translates into equivalent circuit parameters or understanding the impact of load and power factor variations on transformer performance, highlighting a persistent gap between theory and application.

To bridge this gap, educators increasingly employ digital and simulation-based tools that promote interactive visualization and experiential learning. Web-based simulations offer a unified platform for modeling, parameter computation, and performance analysis, providing immediate feedback and enabling self-directed exploration. While platforms like MATLAB/Simulink are powerful, their complexity can overwhelm beginners and shift focus from conceptual understanding to software operation. Addressing this, the present study introduces a web-based Transformer Equivalent Circuit & Analysis Tool, designed to allow students to input experimental data, observe real-time circuit behavior, and develop a deeper, more intuitive understanding of transformer operation without the barriers posed by traditional or complex simulation methods.

The analysis of transformer equivalent circuits is widely recognized as a fundamental yet conceptually challenging topic within undergraduate electrical engineering curricula, highlighting the need for innovative educational approaches that connect abstract theory with practical laboratory experience [1]. The development of web-based and virtual tools, such as the "Transformer equivalent circuit and analysis tool" described in the abstract, is strongly supported by recent literature emphasizing simulation-based learning as a means to enhance student engagement and technical understanding [2]–[5]. This review synthesizes key studies on the use of simulation and web-based tools in electrical engineering education, with a focus on transformer analysis and equivalent circuits. In addition, it integrates online instructional resources, interactive modules, and real-world engineering problems to improve student engagement and facilitate self-directed learning compared to traditional lecture methods.

In modern engineering education, computer-based learning platforms are increasingly valued for their flexibility, interactivity, and stability [1]. The global transition to e-learning, accelerated during recent years, has particularly affected courses in electrical machines, where hands-on laboratory experience is essential [4]. Virtual laboratories (VLabs) have emerged as an effective alternative, offering remote and flexible learning opportunities when access to physical facilities is limited [6], [7]. VLabs serve multiple pedagogical functions:

- Preparation and reinforcement: they provide preparatory exercises before physical lab sessions and enable students to verify experimental results against accurate simulations [1].
- Access and equity: VLabs support diverse learning modes, allowing students to conduct hands-on activities from any location, promoting inclusive and equitable education [6].
- Conceptual deepening: by enabling repeated experimentation in a safe, low-cost environment, virtual tools allow students to collect extensive data, fostering deeper understanding and critical thinking skills [3], [7], [8].
- Real-time interaction: by producing accurate simulated measurement results and enhances students' practical skills compared to traditional physical lab methods [9], [10].

Computational platforms, particularly MATLAB/Simulink, are widely used to model and simulate core transformer concepts [11], [12]. Simulink-based virtual laboratories replicate standard DC, open circuit (OC), short circuit (SC), and load tests, enabling students to calculate equivalent circuit parameters critical for performance metrics such as efficiency and voltage regulation [1], [13]. Accurate models demonstrate minimal error relative to physical transformers, validating their instructional effectiveness [14]. The models, built with both block-diagram and Simscape approaches and validated against the built-in transformer block, allow parameter modification and enhance student learning of transformer behavior in lieu of physical labs [12]. Dynamic models of single-phase two-winding transformers and auto-transformers allow students to manipulate system parameters directly, reinforcing conceptual understanding and bridging the gap between theoretical models and practical measurements [11], [15]. Beyond desktop simulations, web-based platforms with graphical interfaces (e.g., Python- or MATLAB-based GUIs) unify calculations for transformer parameters, voltage regulation, and efficiency [16]. Such tools allow users to input experimental data, nominal ratings, and test results, enabling real-time visualization of operating conditions. Consolidating multiple solution approaches—including single-phase, three-phase, and per-unit methods—within a single interactive environment mirrors the design philosophy of the proposed web-based tool. Moreover, a student behavior simulator based on a Decision Transformer that generates synthetic student–ITS interaction data to address the scarcity of real training datasets is proposed in [17]. The simulated data closely mimic real students' action distributions and can improve the training efficiency and personalization of intelligent tutoring systems.

Interactive simulations support active learning by providing immediate visual feedback, allowing students to explore how changes in load, voltage, and power factor affect transformer behavior in real time [13]. Integrating virtual tools with pedagogical strategies such as problem-based learning (PBL) has been shown to enhance problem-solving skills and conceptual understanding in foundational electrical subjects [2]. Equally important is the role of the instructor as a human mediator, guiding students in the purposeful use of VLabs, designing activities, and evaluating learning outcomes. Effective integration of such tools within the curriculum ensures that students not only acquire technical skills but also develop higher-order cognitive abilities, such as critical thinking and problem-solving. The proposed web-based tool, designed as both a student resource and an instructor demonstration aid, aligns with these educational principles.

Accurate transformer modeling depends on precise equivalent circuit parameters, typically derived from OC and SC tests [18]. While traditional laboratory methods provide these values, students often struggle to connect test results to abstract mathematical models and phasor diagrams. Simulation software like MATLAB/Simulink has been widely employed to visualize these calculations and reinforce understanding in undergraduate courses [19].

For situations where physical testing is impractical, non-interruptive optimization algorithms—such as genetic algorithms (GA) [20], particle swarm optimization (PSO) [18], artificial hummingbird optimizer (AHO), jellyfish search optimizer (JS), slime mold optimizer [21], gravitational search algorithm (GSA), and chaotic optimization approach (COA) [18]—have proven effective in accurately estimating single-phase transformer equivalent circuit parameters (SPTECPs). These techniques minimize the error between measured and calculated terminal quantities, such as primary and secondary currents and voltages, and reflect the function of the “parameter calculator” module in the proposed tool.

Advanced transformer modeling can be developed by incorporating complex real-world effects to enhance simulation accuracy. An equivalent circuit model that accounts for long-distance conductor effects and frequency-dependent parameters is developed and validated against measured impulse frequency responses, improving predictive accuracy of transformer winding behavior [22]. Complementing this, a saturable three-phase transformer model is proposed to analyze the impact of geomagnetically induced currents (GICs), demonstrating how DC bias and saturation distort transformer performance [23]. Together, these works highlight the importance of sophisticated, physics-based modeling approaches for both research and educational simulations. Their methodologies provide valuable insights for developing interactive tools that bridge theoretical models and real-world transformer behavior.

Simulation-based, interactive platforms that integrate MATLAB/Simulink with GUIs have been validated as effective in enhancing student comprehension and confidence in transformer diagnostics. By enabling real-time manipulation of operational conditions and providing immediate visual feedback, these tools reinforce the connection between theoretical models and practical outcomes [24], [25].

This article introduces a novel, web-based interactive tool specifically designed to address persistent challenges in teaching and learning transformer equivalent circuits. Unlike traditional instructional methods or static simulations, this tool integrates theoretical models, laboratory test data, and dynamic visualizations into a single, cohesive learning environment. It enables students to calculate equivalent circuit parameters, analyze voltage regulation, and explore the effects of varying load and power factor conditions in real time. By providing immediate feedback and interactive phasor visualizations, the tool enhances conceptual understanding, fosters active learning, and bridges the gap between abstract theory and practical experimentation. The study further contributes to engineering education by presenting the design framework, pedagogical rationale, and evaluation of this tool as a replicable model for integrating simulation-based learning into electrical engineering curricula.

While existing platforms offer powerful simulation capabilities, they often come with a steep learning curve or require software installation, creating barriers to access. The literature highlights a need for a lightweight, highly accessible, and pedagogically focused tool that seamlessly integrates theoretical concepts with empirical data analysis. This study addresses that need by developing and evaluating a browser-based platform designed specifically for intuitive exploration of transformer principles. To guide this evaluation, the study is framed by the following research questions:

- How do electrical engineering students perceive the usability and pedagogical effectiveness of the interactive web tool for learning transformer equivalent circuits? (RQ1)
- To what extent does the tool, according to students’ self-reported experiences, help in connecting abstract theoretical models with the practical data obtained from laboratory tests? (RQ2)
- Which specific features of the tool (e.g., real-time calculations, dynamic phasor diagrams, step-by-step solutions) are identified by students as being most beneficial to their learning process? (RQ3)

2. THEORETICAL FRAMEWORK

The transformer equivalent circuit provides a fundamental representation of transformer behavior under various operating conditions, bridging theoretical analysis with practical performance evaluation. Typically, the equivalent circuit is referred to one side of the transformer—commonly the primary—though it can be mathematically referred to the secondary using the turns ratio $a = N_1/N_2$. The model comprises a series branch, representing winding resistance (R_{eq}) and leakage reactance (X_{eq}), which accounts for copper losses and leakage flux, respectively, and a shunt branch, representing the magnetizing branch with core-loss resistance (R_c) and magnetizing reactance (X_m), which models hysteresis and eddy current losses along with the magnetizing current necessary to establish the flux. Accurate determination of these parameters relies on two standard tests: the open-circuit test (OCT) and the short-circuit test (SCT). In the OCT, usually conducted on the low-voltage side with the high-voltage side open, measurements of input voltage (V_{oc}), current (I_{oc}), and power (P_{oc}) enable the calculation of the shunt branch parameters. Conversely, the SCT, performed on the high-voltage side with the low-voltage side shorted, provides data (V_{sc}, I_{sc}, P_{sc}) to determine the series branch parameters. Consistency checks, such as ensuring $I_c \leq I_{oc}$and $R_{eq} \leq Z_{eq}$, are necessary to validate the test data. The equations to find the components are as:

$$I_c = \frac{P_{oc}}{V_{oc}} \quad (coreloss\ component) \tag{1}$$

$$I_m = \sqrt{{I_{oc}}^2 - {I_c}^2} \quad (magnetizing\ component) \tag{2}$$

$$R_c = \frac{V_{oc}}{I_c} \tag{3}$$

$$X_m = \frac{V_{oc}}{I_m} \tag{4}$$

$$Z_{eq} = \frac{V_{sc}}{I_{sc}} \tag{5}$$

$$R_{eq} = \frac{P_{sc}}{{I_{sc}}^2} \tag{6}$$

$$X_{eq} = \sqrt{{Z_{eq}}^2 - {R_{eq}}^2} \tag{7}$$

Voltage regulation (VR) is a critical performance indicator that quantifies the change in secondary voltage from no-load to full-load conditions, typically expressed as a function of load current and power factor. The no-load voltage (V_{nl}) is compared against the full-load voltage (V_{fl}) at a given power factor, which can be derived using Kirchhoff's voltage law (KVL) applied to the transformer equivalent circuit. By considering the current phasor angle relative to the reference voltage, the corresponding power factor can be determined, allowing calculation of voltage drop or rise under various loading scenarios. For comprehensive analysis, voltage regulation is evaluated across a range of load currents, from zero to rated full load, and plotted for multiple power factors, offering a visual and quantitative assessment of transformer performance. Integration of these theoretical principles within a computational platform enables real-time observation of equivalent circuit behavior and supports enhanced conceptual understanding through interactive simulation.

3. METHOD

This study employed an exploratory mixed-methods research design to evaluate the effectiveness of an interactive, web-based transformer analysis tool. This approach was chosen as it is well-suited for a pilot investigation, allowing for the collection of both quantitative data on user perceptions (via Likert scales) and rich qualitative insights (via open-ended questions) to inform future development and broader implementation**.** The methodology consisted of three stages: i) development of the simulation tool; ii) classroom deployment and student interaction; and iii) student perception and usability evaluation via a structured questionnaire.

3.1. Tool development and design approach

The web-based "transformer equivalent circuit and analysis tool" was designed using a constructivist learning approach, emphasizing real-time feedback, active experimentation, and visual reinforcement of theoretical concepts. The tool was developed as a self-contained, single-page HTML application, ensuring maximum accessibility with no server-side dependencies. All calculations are performed on the client-side using native JavaScript. Interactive visualizations, including phasor diagrams and performance curves, are rendered dynamically using the Plotly.js open-source library, while the equivalent circuit diagrams are generated as scalable vector graphics (SVG) for clarity and scalability. Phasor calculations for voltage regulation analysis are handled robustly by a custom JavaScript Complex number class, enabling accurate manipulation of vector quantities. The tool consisted of three integrated modules:

– Parameter calculator: allowed students to enter transformer ratings and laboratory test measurements to automatically compute equivalent circuit parameters, including core-loss resistance (Rc), magnetizing reactance (Xm), equivalent resistance (Req), and equivalent reactance (Xeq), as shown in Figure 1. These calculations were automatically displayed with step-by-step derivations and embedded error checking (e.g., validating that $Psc/Isc^2 \leq Vsc/Isc$ to prevent non-physical values).
– Voltage regulation analyzer: enabled students to vary load level and power factor (lagging, leading, unity), as shown in Figure 2, and visualize voltage regulation calculations, transformer phasor diagrams, and VR-versus-load plots in real time. The phasor display and ζ-based drop computation were rendered interactively using complex arithmetic routines embedded in the code.
– Theory and formulas reference: provided an embedded conceptual repository summarizing equivalent circuit theory, test equations, and voltage regulation formulas, enabling rapid connection between theory and simulation output.

This design strategy was intended to reduce cognitive load by transitioning students from symbolic transformer models to visual, parameter-driven analysis aligned with laboratory practice.

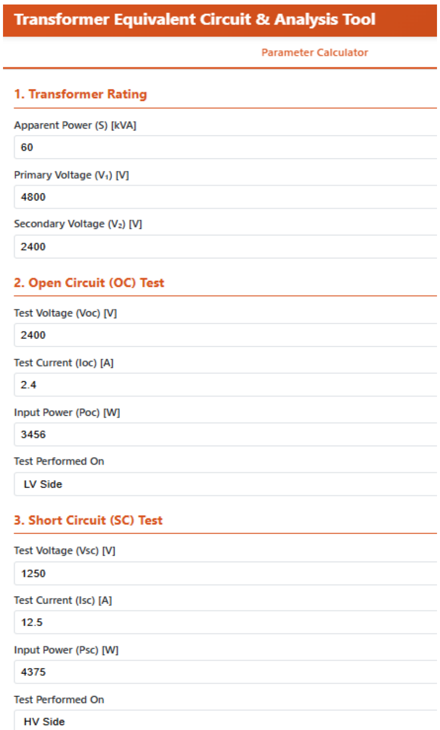

Figure 1. The tool parameter calculator

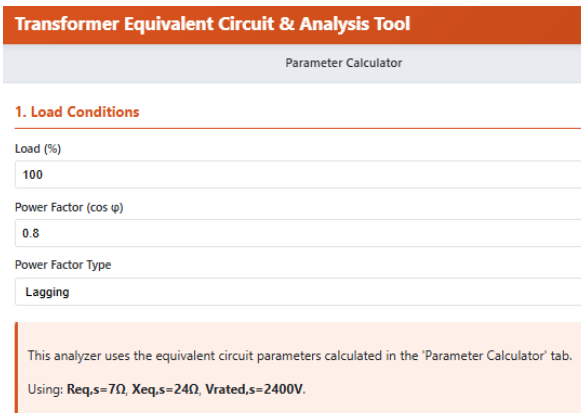

Figure 2. The voltage regulation analyzer

3.2. Classroom deployment and student interaction

The tool was deployed as part of the EENG482: electrical systems simulation course, a required module for electrical engineering students. Students engaged with the tool after completing laboratory open-circuit and short-circuit transformer tests, ensuring alignment between digital simulations and hands-on activities. Students accessed the tool through a web browser and completed structured learning exercises involving inputting actual laboratory OC/SC values, observing auto-computed equivalent-circuit parameters, comparing primary- and secondary-referred circuits, exploring voltage regulation under various loading and power-factor conditions, and interpreting phasor and performance plots.

3.3. Data collection instrument

Following the interaction, students completed the evaluation questionnaire. A structured questionnaire was administered to measure usability, conceptual support, perceived learning improvement, and engagement. The instrument consisted of Likert-scale items (1–5) and open-ended questions across six dimensions. These dimensions were adapted from established usability and educational technology evaluation frameworks, focusing on key aspects of the student learning experience. The dimensions were: ease of use and accessibility, conceptual understanding, feature-specific learning value, comparison with traditional methods, student engagement and confidence, and overall evaluation and suggestions.

Representative items included evaluating interface clarity, the usefulness of auto-generated diagrams and phasor plots, and motivation to explore "what-if" scenarios. Quantitative data from the 5-point Likert-scale responses (1=strongly disagree to 5=strongly agree) were analyzed for descriptive statistics and internal consistency reliability (Cronbach's alpha). Qualitative responses were coded using thematic content analysis to identify common strengths, usability issues, and perceived learning benefits. Participants were informed that their feedback was for research and instructional improvement purposes only and would not affect their course grade, consistent with ethical guidelines for educational research.

4. RESULTS AND DISCUSSION

4.1. Web-tool performance results

A total of 25 undergraduate electrical engineering students has participated in the study. After the students' interaction with the online tool, the tool successfully performed equivalent-circuit parameter calculation from OC/SC test inputs, as seen in Figure 3, automatic derivation of R_c, X_m, R_{eq}, X_{eq}, real-time voltage regulation simulation vs. load and power factor, as shown in Figure 4, interactive phasor diagrams and VR-performance curves, and a show-step calculation feature and theory reference tab.

Students consistently reported that inputting values instantly updated results and diagrams, and the VR and phasor plots changed correctly with PF lag/lead. In addition to that, the tool responded reliably with no crashes or incorrect outputs. These observations validate the tool functionality and confirm it meets the intended learning objectives.

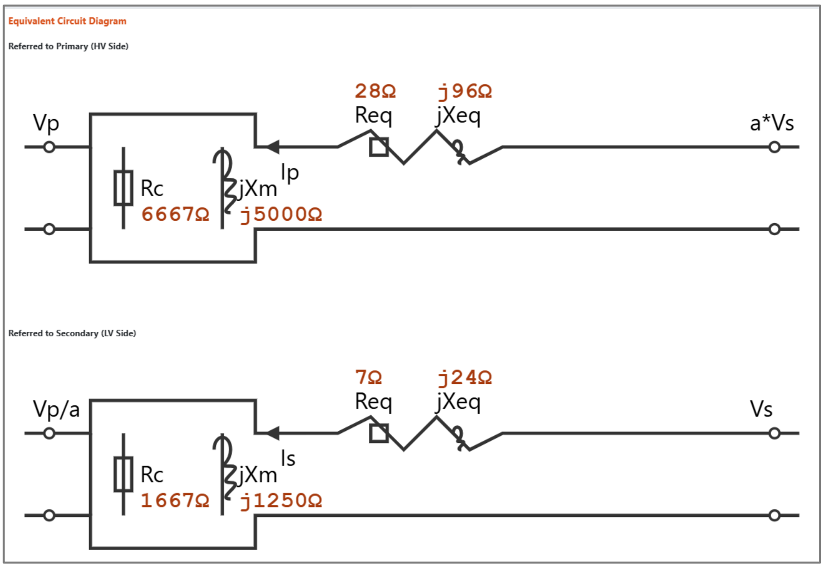

Figure 3. The equivalent circuit diagram referred to the primary and secondary sides

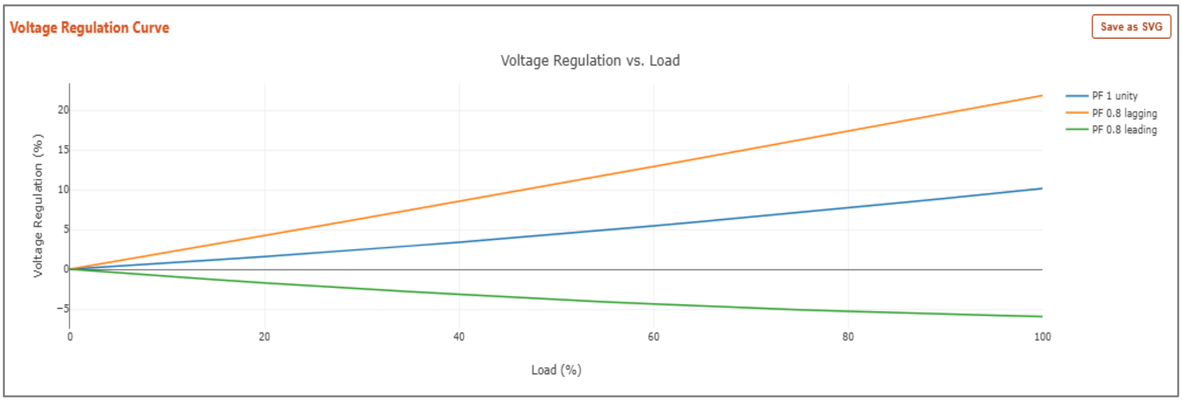

Figure 4. Voltage regulation versus load for different power factors

4.2. Questionnaire descriptive results

All 22 Likert-scale questions of the questionnaire were analyzed. Internal consistency reliability analysis indicated strong reliability across the questionnaire domains, with an overall Cronbach's α=0.92, exceeding the recommended 0.70 threshold for educational research instruments. The detailed reliability results shown in Table 1 demonstrate that the questionnaire items were highly consistent in measuring student perceptions.

Table 1. Cronbach's measure of the student questionnaire

Section	Cronbach's α
Ease of use and accessibility	0.88
Conceptual understanding	0.91
Feature-specific usefulness	0.90
Comparison with traditional methods	0.87
Engagement and confidence	0.85
Overall	0.92

The ease-of-use results as shown in Table 2 confirmed strong usability and very high satisfaction with a mean M=4.42 and a standard deviation SD=0.54. Conceptual understanding results as shown in Table 3 showed major learning gains in key transformer topics, with M=4.38 and SD=0.62. Moreover, the feature-specific evaluation results as shown in Table 4, with M=4.51, have proved that students have greatly valued the visualization of theory. Regarding the comparison with traditional learning as shown in Table 5, having M=4.4, 93% reported time savings, significant efficiency gains, increased interest, and greater experimentation, in addition to feeling more confident post-use. Figure 5 illustrates the reported time saved by students.

Table 2. Ease-of-use results (N=25)

Statement	Agree (%)
Intuitive interface and navigation	92.8
Clear input steps	85.7
Visual feedback is easy to interpret	100
The tool worked reliably	92.8

Table 3. Conceptual understanding results (N=25)

Statement	Agree (%)
OC/SC test → parameters understanding	85.7
Primary vs secondary visualization	92.8
Voltage regulation and PF effect	85.7
Phasor diagram helpful	71.4
Theory → application link	92.8

Table 4. Feature-specific evaluation results (N=25)

Feature	Helpful (%)
Real-time updating	92.8
Show calculation steps	85.7
Equivalent circuit diagrams	85.7
VR vs Load plots	92.8
Theory tab	92.8

Table 5. Comparison with traditional learning results (N=25)

Statement	Agree (%)
Better than lecture/manual only	100
Reduced time and effort	100
Encouraged experimentation	85.7
Increased interest	85.7
More confident post-use	85.7

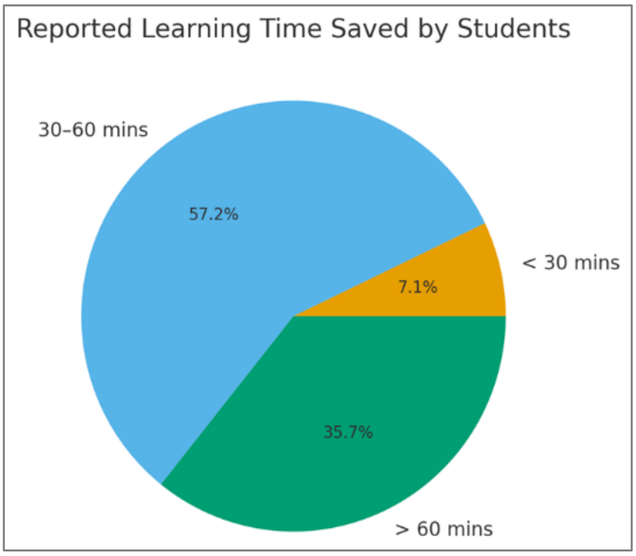

Figure 5. Student-reported time saved on learning tasks compared to traditional methods (N=25)

Concerning the open-ended feedback, the most liked features, as students have commented, are instant/real-time updates, step-by-step calculations, a fast, simple, clean interface, phasor and VR visualization, and time-saving vs MATLAB/manual. Overall, and as mentioned before, the tool has shown strong endorsement for continued adoption, with an overall agreement percentage of 92.8% regarding positive agreement, time savings, and reliability.

4.3. Discussion

This section interprets the study's findings by directly addressing the research questions outlined in the introduction. The results indicate that the web-based tool was perceived by students as a highly effective and usable supplement for learning transformer concepts.

The first research question (RQ1) perceptions of usability and pedagogical effectiveness, examined students' perceptions of the tool's usability and overall pedagogical effectiveness. The quantitative data show exceptionally strong usability, with 100% of students (25/25) agreeing that the visual feedback was easy to interpret and over 92% finding the interface intuitive, as shown in Table 2. This high degree of usability is critical, as it suggests the tool's design successfully avoids imposing extraneous cognitive load; students can focus on the engineering concepts rather than struggling with the software itself. The open-ended feedback supported this, with one student noting the tool has a "fast, simple, clean interface." The tool's overall effectiveness is further evidenced by the 100% agreement that it was "better than lecture/manual only" as shown in Table 5, highlighting it is perceived value as a pedagogical resource.

The second research question (RQ2) bridging the theory-practice gap, asked if the tool helped connect abstract theory with practical laboratory data. The results strongly affirm this. A significant 92.8% of students agreed that the tool clarified the link between theory and application, and 85.7% confirmed it improved their understanding of how OC/SC test results translate into circuit parameters as shown in Table 3. This suggests the tool's core design—allowing students to input their own experimental data and immediately see the resulting circuit model and performance plots—directly addresses the well-documented pedagogical gap. By automating the laborious calculations, the tool appears to have freed students' cognitive resources to focus on the conceptual connections. As one student commented, the "step-by-step calculations" feature was crucial for "linking the formulas from class to the final numbers."

The third research question (RQ3) most beneficial learning features, sought to identify the specific features students found most valuable. The feature-specific data in Table 4 is particularly revealing. The highest-rated features were 'Real-time updating,' 'VR vs Load plots,' and the 'Theory tab' (all 92.8% helpful). This finding underscores the importance of immediate, dynamic feedback in the learning process. The ability to manipulate an input (like the power factor) and instantly observe its effect on a graphical output (the VR curve) supports a constructivist learning model. Students are not just passively consuming information; they are actively building their mental models by testing "what-if" scenarios. The high rating of the 'Phasor diagram' (71.4% helpful) and 'Equivalent circuit diagrams' (85.7%) further indicates the value of visual representations in demystifying abstract concepts that are otherwise confined to mathematical equations.

In summary, the discussion of the results validates the pedagogical approach and system design. The interactive visualizations foster deeper learner involvement, aligning with constructivist principles, while the automation of calculations reduces extraneous cognitive load, allowing students to focus on conceptual exploration. The strong positive feedback and perceived time savings as shown in Figure 5 suggest that tools like this can significantly enhance student engagement and learning efficiency in challenging engineering topics.

5. CONCLUSION

This study presented the design, implementation, and pedagogical evaluation of an interactive web-based tool developed to support student learning of transformer equivalent circuits and voltage regulation. The tool successfully bridged the gap between theoretical analysis and laboratory data interpretation by integrating real-time computation, dynamic phasor visualization, equivalent-circuit diagrams, and an embedded theory reference module.

Quantitative and qualitative results from an evaluation with 25 undergraduate students demonstrated strong agreement that the tool improved conceptual understanding, enhanced engagement, reduced cognitive effort, and encouraged exploratory learning when compared with traditional methods. Students particularly valued the immediate visual feedback, step-by-step calculation transparency, and the ability to manipulate load and power factor to observe corresponding performance changes in real-time. These findings reinforce the importance of interactive educational tools that transform abstract electrical engineering concepts into intuitive, visual experiences. The tool, therefore, represents a valuable supplementary learning resource for power engineering education. Its browser-based, self-contained design makes it accessible without installation, supporting flexible deployment across in-class demonstrations, laboratory integration, and independent student learning.

We acknowledge several limitations in this study. The evaluation was conducted with a small sample of 25 students at a single university, which limits the generalizability of the findings to a wider student population. The study's methodology also relied on self-reported perception data rather than direct measurement of learning gains, for instance, through a pre-test/post-test experimental design. Consequently, while the results indicate a strong positive perception, they do not quantitatively prove an increase in academic performance.

Future research should aim to address these limitations. A quasi-experimental study with a control group could be conducted to quantitatively assess the tool's impact on student exam scores and conceptual understanding. Further development of the tool itself is also planned, with potential expansions to include modules for three-phase transformers, efficiency calculations, and per-unit analysis, thereby increasing its utility across the electrical engineering curriculum.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state no conflict of interest.

DATA AVAILABILITY

The data presented in this study are available on request from the corresponding author. The computational tool is implemented as a single-page HTML and JavaScript application with dynamic plotting via the Plotly.js library, and it is also available upon request.

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