Interactive Edu-Video App for Teaching Electricity and Electronics Principles to Bachelor of Science in Industrial Technology (BSIT) Students

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https://doi.org/10.34190/ejel.24.1.4148

Abstract: Teaching complex electrical and electronic principles to Bachelor of Science in Industrial Technology (BSIT) students presents a significant pedagogical challenge due to the abstract nature of the concepts. Traditional static methods often fail to provide the visualization required for technical mastery. This study aimed to bridge this gap by designing, developing, and evaluating an "Interactive Edu-Video App" for the course Electricity & Electronics Principles at North Eastern Mindanao State University, Philippines. The study utilized a Research and Development (R&D) approach grounded in the ADDIE model, combined with a quasi-experimental design (non-equivalent control group). The participants included 76 BSIT students and 16 experts (instructors and industry practitioners). Data were analyzed using weighted means for validity and t-tests for learning effectiveness. The development phase produced a mobile application integrating interactive hotspots and quizzes based on Cognitive Load Theory. Expert validation rated the app as "Very Satisfactory" (M=3.61) in terms of accessibility and engagement. Experimental results revealed that while baseline knowledge was comparable (p=0.146), the experimental group using the app achieved significantly higher posttest scores (M=25.45) compared to the control group (M=17.39), with a significant learning gain (t=18.781, p<0.001). The findings confirm that interactive video is not merely a supplementary tool but a superior pedagogical strategy for technical education. The study contributes a validated, scalable mobile learning model that enhances conceptual mastery in TVET, offering a practical solution for resource-constrained industrial technology programs.

Keywords: TVET, Interactive video, ADDIE model, Electrical technology, Mobile learning, Instructional design

1. Introduction

The rapid evolution of Industry 4.0 demands that students in electrical technology possess not only theoretical knowledge but also robust practical competencies to navigate a technology-driven world (Bekhoeva, Ramazanova and Bekoeva, 2022, Ma, 2024). Consequently, Technical-Vocational Education and Training (TVET) institutions are under pressure to revise curricula to include advanced concepts such as the Internet of Things (IoT) and intelligent manufacturing (Verdejo Espinosa et al., 2023). However, teaching foundational subjects like Electricity and Electronics Principles remains a significant pedagogical hurdle. Concepts such as voltage, current, and resistance are invisible and abstract, making them difficult for Bachelor of Science in Industrial Technology (BSIT) students to conceptualize through traditional lectures alone (Al-Ali, 2021, Ibanga, Dawasa and Yaro, 2023).

A critical gap exists in the delivery of these technical subjects. While the COVID-19 pandemic accelerated the adoption of e-learning, many resources used in TVET remains "static"—consisting largely of PDFs or passive video lectures that do not fulfill the varied learning requirements of technical students (Dotsenko, 2022, Utari and Mukhaiyar, 2020). Passive observation often leads to disengagement and fails to bridge the gap between theory and practice. Unlike general education, technical education requires active visualization and manipulation of variables. Although interactive multimedia has shown promise in other fields, there is a scarcity of validated, interactive mobile applications specifically designed for the BSIT electricity curriculum in the Philippine context.

Cite this article: Grustan, K.J.C. et al. 2025. “Interactive Edu-Video App for Teaching Electricity and Electronics Principles to Bachelor of Science in Industrial Technology (BSIT) Students”, *Electronic Journal of e-Learning*, 24(1), pp 36-44, https://doi.org/10.34190/ejel.24.1.4148

To address this gap, this study aimed to design, develop, and evaluate an Interactive Edu-Video App for BSIT students at North Eastern Mindanao State University (NEMSU). Grounded in the ADDIE instructional design model, the study sought to: (1) develop a mobile learning tool that integrates interactive elements (quizzes, hotspots) to reduce cognitive load; (2) validate the app's acceptability through expert review; and (3) determine its effectiveness in improving learning outcomes compared to conventional static materials.

2. Literature Review

Challenges in Technical Education

Teaching electricity poses unique challenges due to the abstract nature of the phenomena. Misconceptions regarding circuit behaviors are common because students cannot "see" the electron flow (Burde, Weatherby and Wilhelm, 2022, Moodley and Gaigher, 2017). Traditional methods often rely on rote memorization of calculations, which hinders the development of the deep conceptual understanding required for industry troubleshooting (Fan et al., 2023, Kang and Liang, 2024). Furthermore, resource constraints in developing countries often result in limited laboratory access, making digital simulation and visualization critical for bridging the theory-practice gap (Hermawati, 2022).

The Role of Interactive Video in TVET

While video is a staple in e-learning, passive video consumption often fails to sustain the cognitive engagement necessary for complex learning (Buentello-Montoya and Montes-Montejo, 2022). In contrast, interactive video—which requires user inputs such as answering embedded questions or navigating branching scenarios—transforms the learner from an observer to a participant (Dahlan et al., 2023). Empirical studies in STEM education indicate that interactivity improves retention by forcing the learner to actively process information (Peisen and Jr., 2023). However, most existing studies focus on general engineering; there is a need for specific applications within the vocational and industrial technology sector (Hasanuddin, Asgar and Jayadi, 2023).

Theoretical Framework: Designing for Cognitive Efficiency

The design of the Interactive Edu-Video App is theoretically grounded in Mayer's Cognitive Theory of Multimedia Learning (CTML) and Sweller's Cognitive Load Theory (CLT). CTML asserts that learning is optimized when visual and auditory channels are processed simultaneously but not overwhelmed (Mayer, 2021). The app applies Mayer's Signaling Principle (highlighting key circuit parts) and Segmenting Principle (breaking complex laws into short, user-controlled clips) to manage processing capacity. CLT emphasizes minimizing extraneous cognitive load (distractions) to maximize germane load (schema construction) (Noetel et al., 2021, Sweller, Ayres and Kalyuga, 2011). By embedding quizzes directly into the video timeline, the app aligns with the interactivity effect, ensuring that students test their understanding before moving to more complex concepts. This theoretical alignment distinguishes the proposed app from standard repository-based e-learning tools.

3. Methods

3.1 Research Design

This study employed a Developmental-Quasi-Experimental research design. The developmental phase followed the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model to systematically construct the Interactive Edu-Video App. The evaluation phase utilized a non-equivalent control group pretest-posttest design to measure the app's effectiveness. This dual approach allowed for both the creation of a validated instructional tool and the empirical testing of its impact on student learning outcomes.

3.2 Research Setting and Participants

The study was conducted at North Eastern Mindanao State University (NEMSU) - Cantilan Campus. The participants were selected using purposive sampling (Table 1).

- **Validators (N=16):** Comprised of 6 Teacher Experts (Instructors/RMEs) and 10 Student Experts (NCII holders) who assessed the app's usability and content.
- **Experimental Subjects (N=76):** First year BSIT students enrolled in *ELC 111 - Electricity and Electronics Principles*. They were divided into the Experimental Group (n=38) which used the interactive app, and the Control Group (n=38) which used traditional static materials.

Table 1: Research Participants

	Category	Number of Respondents
Validators (N=16)	Teacher Experts (Instructors, Professors, RME)	6
	Student Experts (OJT, NCII Holders)	10
Experimental Subjects (N=76)	BSIT Learners - Section ELC 1Q	25
	BSIT Learners - Section ELC 1R	24
	BSIT Learners - Section ELC 1L	27
	TOTAL	92

3.3 Research Instruments

- Validation Questionnaire: Adapted from Rice and Ortiz (2021), assessing four dimensions: Accessibility, Active Engagement, Advocacy for Inclusion, and Accountability. It used a 5-point Likert scale.
- Learning Achievement Test: A 50-item multiple-choice test covering ELC 111 competencies. This instrument underwent pilot testing and item analysis to ensure validity and reliability before being used as the pretest and posttest.

3.4 Data Collection Procedure

- Phase 1 (Development): A needs analysis was conducted via interviews to identify learning gaps. Based on these findings, the app was designed using storyboards and developed using LUMI software.
- Phase 2 (Validation): The beta version was evaluated by the expert panel using the Validation Questionnaire. Feedback was incorporated into the final build.
- Phase 3 (Experiment): Both groups took the pretest. The Experimental Group utilized the Interactive Edu-Video App for a 6-week intervention period, while the Control Group utilized standard PDF modules and static video lectures. Both groups took the posttest immediately after the intervention.

3.5 Data Analysis

Quantitative data were analyzed using SPSS. Weighted Means were used to interpret expert validation ratings. For the experimental phase, Independent Samples t-tests were used to check for baseline equivalence (pretest), and Paired Samples t-tests and Independent t-tests were used to determine significant differences in learning gains (posttest). Significance was set at $p < 0.05$.

4. Results

4.1 System Development Results (ADDIE Output)

The application of the ADDIE model yielded a fully functional interactive mobile learning tool tailored to BSIT students.

4.1.1 Analysis phase output

The thematic analysis of student interviews revealed critical gaps in existing materials. As shown in Table 2, students expressed a strong "Need for Interactive Content" and "Desire for Instant Feedback" to combat the passivity of traditional lectures.

Table 2: Thematic Analysis of Student Needs Assessment Interview Responses

CODE	THEME	ILLUSTRATIVE QUOTES
Lack of Engagement with Existing Videos	Need for Interactive Content	"The videos are okay, but they become dull pretty fast." "I often lose concentration after a short time." "It's just passive watching without any involvement."
Difficulty Grasping Concepts	Enhanced Learning through Interaction	"Sometimes, I don't fully grasp the material being shown." "I wish there was a way to ask questions or practice alongside the video."

CODE	THEME	ILLUSTRATIVE QUOTES
Preference for Hands-On Activities	Active Participation	"I learn better by doing, not just watching." "Practical exercises help me understand the material more clearly."
Desire for Instant Feedback	Interactive Feedback Features	"It would be helpful if the video could tell me whether I'm doing something correctly as I follow along." "I want immediate confirmation if I'm on the right track."
Need for Customizable Learning Speed	Self-Paced Learning	"Sometimes the videos move too quickly, and I can't keep up." "I'd like to be able to pause and try things at my own speed."
Struggling to Retain Information	Better Retention through Interaction	"I tend to forget a lot of what I watch afterward." "If I could interact with the content, I think I would remember it more effectively."

4.1.2 *Design phase output*

Guided by the analysis, the app's architecture was structured to reduce cognitive load. The content flow (Figure 1) and visual storyboards (Figure 2) prioritized "segmenting" complex electrical laws into manageable interactive chunks.

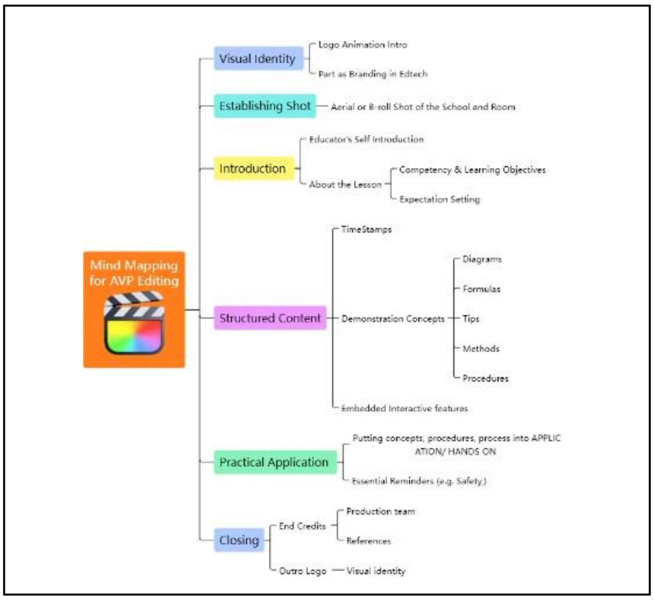

Figure 1: Mind map of Edu-video Lesson

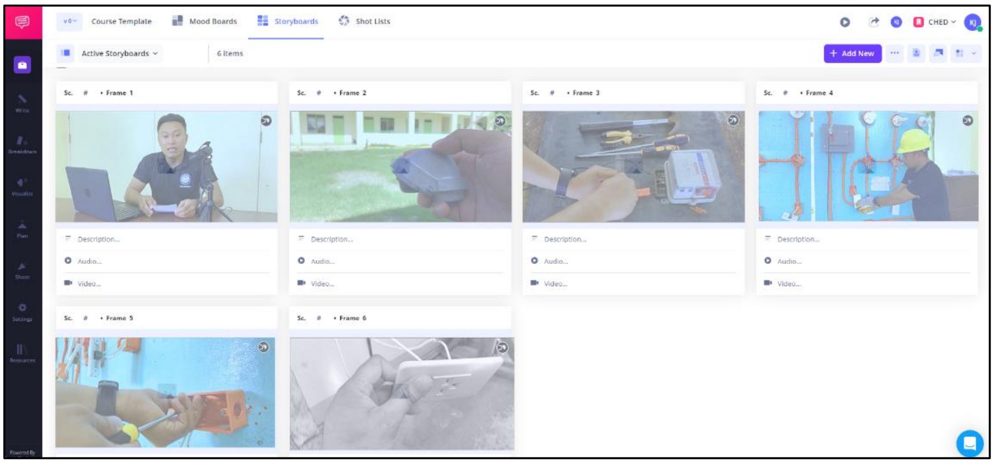

Figure 2: Storyboard for Edu-Video Lesson

4.1.3 *Development phase output*

The final output was the "Interactive Edu-Video App" (APK format) (Figure 4&5). Unlike static videos, this app integrated "hotspots" and "pop-up quizzes" using LUMI software (Figure 3). This allows students to engage with the video timeline directly, transforming passive watching into active problem-solving.

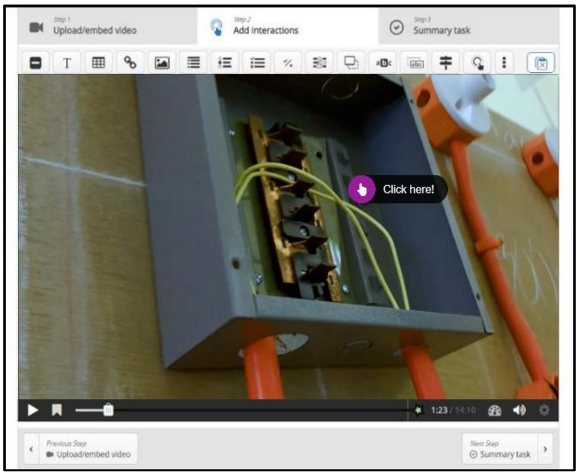

Figure 3: Interactive features using LUMI

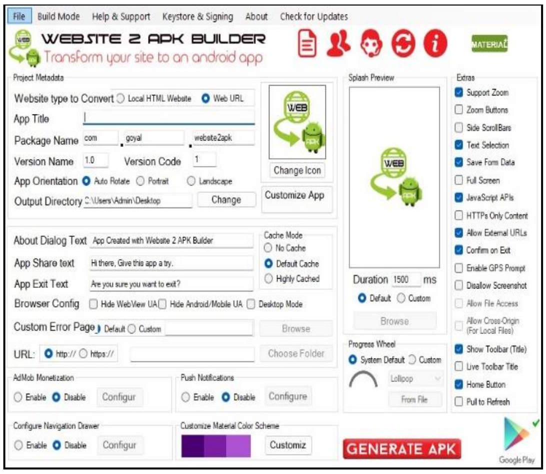

Figure 4: Converting HTML5 to APK

Figure 5: Application Development Results

4.2 Expert Validation Results

The Interactive Edu-Video App underwent validation by both teacher experts and student experts using an adapted instrument assessing Accessibility (ACC), Active Engagement (AE), Advocacy for Inclusion (AI), and Accountability (AC) (Rice and Ortiz, 2021).

4.2.1 *Teacher expert validation*

As summarized in Table 3, teacher experts provided high ratings across all dimensions. Each indicator's average weighted mean fell into the 'Very Satisfactory' category. Accessibility received an average score of 3.50, Active Engagement 3.58, Advocacy for Inclusion 3.57, and Accountability 3.58. Specific items receiving particularly high ratings included the app offering feedback (AE item 7: 4.00) and being viewable on various devices (ACC item 3: 3.67). Areas noted for potential enhancement included the availability of materials in multiple formats (ACC item 2: 3.00) and transparency regarding affiliations/sources (AC item 2: 3.17).

Table 3: Teacher Experts' Validation Ratings (N=6)

Indicator	Code	Average Weighted Mean	Verbal Description
ACCESSIBILITY	ACC	3.50	Very Satisfactory
ACTIVE ENGAGEMENT	AE	3.58	Very Satisfactory
ADVOCACY FOR INCLUSION	AI	3.57	Very Satisfactory
ACCOUNTABILITY	AC	3.58	Very Satisfactory

Scale interpretation: 3.25-4.00 - Very Satisfactory; 2.25-3.24 – Satisfactory; 1.25-2.24 – Unsatisfactory; 1.24 and below - Poor

4.2.2 Student expert validation

Student experts also rated the app very positively, with all indicators achieving an overall 'Very Satisfactory' description, as shown in Table 4. Accessibility received an average score of 3.62, Active Engagement 3.68, Advocacy for Inclusion 3.67, and Accountability 3.64. Notably, high ratings were given for device compatibility (ACC item 3: 4.00) and the provision of feedback (AE item 7: 4.00). Similar to teacher feedback, areas with relatively lower (though still satisfactory) scores included availability in multiple formats (ACC item 2: 3.20) and revealing affiliations/sources (AC item 2: 3.30).

Table 4: Student Experts' Validation Ratings (N=10)

Indicator	Code	Average Weighted Mean	Verbal Description
ACCESSIBILITY	ACC	3.62	Very Satisfactory
ACTIVE ENGAGEMENT	AE	3.68	Very Satisfactory
ADVOCACY FOR INCLUSION	AI	3.67	Very Satisfactory
ACCOUNTABILITY	AC	3.64	Very Satisfactory

Scale interpretation: 3.25-4.00 - Very Satisfactory; 2.25-3.24 – Satisfactory; 1.25-2.24 – Unsatisfactory; 1.24 and below - Poor

4.3 Effectiveness Evaluation Results

The effectiveness of the Interactive Edu-Video App was evaluated using a quasi-experimental design involving BSIT ELC 1 students (N=38 per group, Control and Experimental) enrolled in the Electricity and Electronic Principles course. Pretest and posttest scores were analyzed.

4.3.1 Learning performance (pretest and posttest scores)

Mean scores and standard deviations are summarized in Table 5, covering both the initial (pretest) and final (posttest) assessments for each group. For the control group, average scores increased slightly between the initial assessment (M=15.18) and the concluding one (M=17.39). Using the Interactive Edu-Video App, the experimental group exhibited a substantially larger increase, from a pretest mean of 14.42 to a posttest mean of 25.45. Score dispersion among the experimental participants decreased notably from the initial to the final test.

Table 5: Pretest and Posttest Performance of Control and Experimental Groups (N=38 each)

Group	Test	Mean	Std. Deviation
Control	Pretest	15.18	2.481
	Posttest	17.39	2.074
Experimental	Pretest	14.42	2.035
	Posttest	25.45	1.639

4.3.2 *Statistical comparisons (T-tests)*

Statistical tests were conducted to evaluate whether the observed variations were statistically significant (Table 6). An independent samples t-test confirmed no statistically substantial difference between the control and experimental groups' pretest scores ($p = 0.146$), indicating comparable baseline knowledge. Paired samples t-tests revealed statistically substantial improvements from the pretest to the post-test within both groups: the control group ($p < 0.001$) and, more significantly, the experimental group ($p < 0.001$). Crucially, an independent samples t-test comparing the posttest scores showed a highly statistically substantial difference between the groups ($p < 0.001$), with the experimental group achieving significantly higher scores than the control group after the intervention period.

Table 6: T-test Results for Pretest and Posttest Comparisons

Comparison	t-statistic	p-value	Decision	Interpretation (Statistical)
Paired T-test: Control Group (Pretest vs Posttest)	5.041	< 0.001	Reject H_0	Significant difference within the control group
Paired T-test: Experimental Group (Pre vs Post)	22.864	< 0.001	Reject H_0	Significant differences within the experimental group
Independent T-test: Pretest (Control vs Exp.)	1.466	0.146	Fail to Reject H_0	No significant difference between the groups' pretest
Independent T-test: Posttest (Control vs Exp.)	18.781	< 0.001	Reject H_0	A significant difference between groups' posttest

5. Discussion

5.1 Development and Validity of the App

The study successfully developed an Interactive Edu-Video App that meets the specific needs of BSIT students. The "Very Satisfactory" ratings from both teachers (M=3.56) and students (M=3.65) confirm that the app is not only technically functional but pedagogically sound. High ratings in Active Engagement validate the design decision to move away from passive MP4 videos. By integrating LUMI software features like hotspots and branching scenarios, the app transformed the viewing experience. This aligns with Mayer's Cognitive Theory of Multimedia Learning, specifically the Signaling Principle, as the interactive elements guided students' attention to critical circuit behaviors that are often missed in static diagrams (Mayer, 2021).

5.2 Effectiveness in Enhancing Learning Outcomes

The most significant finding is the substantial learning gain observed in the experimental group ($t=18.781$, $p<0.001$). While both groups started with equivalent background knowledge, the group using the interactive app outperformed the control group by a wide margin (Posttest M: 25.45 vs. 17.39).

This superiority can be attributed to the reduction of Extraneous Cognitive Load (Sweller, Ayres and Kalyuga, 2011). In the control group, students had to mentally visualize electron flow while reading static text, a process that consumes high cognitive effort. In contrast, the app provided dynamic visualization and immediate feedback through embedded quizzes. This "interactivity effect" prevented the passive "illusion of competence" often seen in video learning (Buentello-Montoya and Montes-Montejo, 2022). Furthermore, the app allowed for self-paced learning—students could replay complex segments (e.g., Ohm's Law calculations) until mastery was achieved, a flexibility not always possible in a rigid classroom lecture.

5.3 Implications for TVET

These findings have profound implications for technical education. They suggest that the difficulty students face in Electricity and Electronics is not necessarily due to the subject's complexity, but the delivery medium's limitations. For TVET institutions facing resource constraints, this study demonstrates that mobile learning applications can serve as effective, low-cost alternatives to expensive simulation hardware for foundational theoretical training.

6. Conclusion

This study confirms that integrating interactivity into educational video significantly enhances the learning outcomes of BSIT students in electrical technology. The Interactive Edu-Video App proved to be a superior pedagogical tool compared to traditional static materials, not merely because it is digital, but because it aligns with cognitive principles of engagement and load reduction. The study concludes that for abstract technical subjects, passive visualization is insufficient; active learner intervention within the content is required for deep conceptual mastery.

7. Recommendations

Based on these findings, the following recommendations are proposed:

1. Instructional Design: TVET educators should transition from repository-based e-learning (uploading PDFs/MP4s) to interactive multimedia design. Tools like LUMI or H5P should be standard in the development of technical modules.
2. Curriculum Integration: Institutions should formally integrate validated mobile apps into the Electricity and Electronics syllabus as supplementary review tools to bridge the gap between classroom theory and laboratory application.
3. Future Research: Future studies should address the limitations of this research by:

- Conducting longitudinal studies to determine if the knowledge retention persists over a full semester.
- Expanding the sample to include multiple TVET institutions to improve generalizability.
- Investigating the app's effectiveness on psychomotor skills (actual wiring tasks) in addition to cognitive knowledge.

Acknowledgement

The authors would like to express their sincere gratitude to the participants of this study, the Bachelor of Science in Industrial Technology students and Professors at North Eastern Mindanao State University – Cantilan Campus and also Industry practitioners, for their time and valuable contributions. Special appreciation is extended to the university administration for granting permission and providing the necessary institutional support to conduct this research. Their cooperation was crucial to the successful completion of this project.

AI Statement: The authors acknowledge the use of specific AI-assisted technologies to support the preparation of this manuscript, adhering to ethical guidelines. Consensus AI was utilized to assist in the discovery of relevant literature during the review phase. Google AI Studio and Grammarly were used exclusively for language refinement, paraphrasing, and grammatical correction to enhance readability and flow. EndNote software was employed for reference management and formatting. The authors confirm that no AI tools were used for data generation, statistical analysis, or the scientific interpretation of results. All data processing (using SPSS), thematic analysis, and conclusions are the original work of the authors. The authors have critically reviewed all AI-assisted output and take full responsibility for the content of the work.

Ethical Statement: This study was conducted in strict adherence to the ethical protocols established by the Research and Development Office of North Eastern Mindanao State University. Ethical approval was granted under the institutional review oversight for social science research (Protocol/Ref: NEMSU-RDO-2025-04). Informed consent was obtained from all participants prior to data collection.

Conflict of Interest Statement: The authors declare that the research was not conducted in the presence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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